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**HIGH ENERGY PHYSICS DIVISION
SEMIANNUAL REPORT OF
RESEARCH ACTIVITIES**

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Table of Contents

I.	Experimental Research Program	1
A.	Experiments With Data	1
1.	Medium Energy Physics Polarization Program	1
2.	Collider Detector at Fermilab	3
a)	Physics Results	3
b)	Run II Planning	3
3.	Non-Accelerator Physics at Soudan	5
a)	Physics Results	5
b)	Experimental Apparatus, Operation and Maintenance	12
c)	Planning Activities	12
4.	ZEUS Detector at HERA	12
a)	Physics Results	12
b)	HERA and ZEUS Operations	16
5.	BNL Polarized Experiments	18
B.	Experiments In Planning Or Construction	18
1.	Polarized Beam Experiments for a RHIC Polarimeter	18
2.	MINOS-Main Injector Neutrino Oscillation Search	19
3.	ATLAS Detector Research & Development	22
a)	Overview of ANL LHC Related R&D Programs	22
C.	Detector Development	22
1.	CDF Detector and DAQ Electronics Development	22
a)	Run II Project	22
2.	ZEUS Detector Upgrade	23
a)	Straw Tube Tracker Readout Electronics	23
3.	ATLAS Calorimeter Design and Construction	23
a)	Structural Design and Analysis	24
b)	Other Design Work	24
c)	Calorimeter Construction	25
d)	Submodule Small Components	27
e)	Module Shipping	27
f)	Building Preparation in 366	28
g)	Calorimeter Instrumentation and Testing	30
h)	Test Beam Program	30
i)	Project Management and Planning	34
4.	MINOS Detector Development	34
5.	Electronics Support Group	37
II.	Theoretical Physics Program	41
A.	Theory	41
1.	Associated Production of Gauginos and Gluinos at Hadron Colliders in Next-to-Leading Order SUSY-QCD	41
2.	Relativistic Corrections to S -Wave Quarkonium Decays	42
3.	Order- $\alpha_s v^2$ Corrections to J/ψ and Upsilon Decays	42
4.	Sparticle Production and Photon Hadron Scattering in NLO QCD	43
5.	Computational Physics (Lattice Gauge Theory)	43
6.	The Triangle Anomaly in Triple-Regge Limits	46

III.	Accelerator Research And Development	47
	A. Argonne Wakefield Accelerator Program	47
	1. Photoinjector Research	47
	2. Plasma Wakefield Experiment	47
	B. MUON Collider R & D	49
	1. Beam Optics in Bent Solenoids	49
	2. The Design of a Lithium Lens	50
IV.	Divisional Computing Activities	51
	A. Grand Challenge Applications	51
	1. Data Access for High-Energy and Nuclear Physics R&D	51
V.	Publications	53
	A. Journal Publications, Conference Proceedings, Books	53
	B. Papers Submitted for Publication	59
	C. Papers or Abstracts Contributed to Conferences	61
	D. Technical Reports and Notes	62
VI.	Colloquia and Conference Talks	64
VII.	High Energy Physics Community Activities	68
VIII.	High Energy Physics Division Research Personnel	71

I. EXPERIMENTAL RESEARCH PROGRAM

I.A. EXPERIMENTS WITH DATA

I.A.1 Medium Energy Physics Polarization Program

The Brookhaven AGS experiments E-897 (η decays to neutrals), E-913 ($\pi^-p \rightarrow N^*, \Delta^* \rightarrow \text{neutrals}$), and E-914 ($K^-p \rightarrow \Lambda^*, \Sigma^* \rightarrow \text{neutrals}$) using the Crystal Ball detector collected the bulk of their data up to 750 MeV/c beam momentum during this period. These experiments tuned up, performed calibrations, and took some data in a two-week period in July, and spent 6-7 weeks in September - November 1998 collecting data. In addition, tests were performed to measure the kaon stopping rate for a planned experiment to measure K_{e3} and K_{e4} decays, to evaluate rates for an experiment with nuclear targets, and to search for $\bar{p}p$ interactions.

The primary η decay modes of interest are 2γ , 3γ , $\pi^0\gamma\gamma$, $3\pi^0$, $3\pi^0\gamma$, and $4\pi^0$, and approximately 20 M η decays were recorded. These measurements will be analyzed by collaborators from Arizona State University, the University of California at Los Angeles, PNPI - Gatchina in Russia, and the University of Regina in Canada. Many pion momenta were measured for E-913 in order to study the reactions $\pi^-p \rightarrow \pi^0n$, $\pi^0\pi^0n$, η^0n , γn , and $\pi^0\pi^0\pi^0n$. These data will be analyzed by physicists from Abilene Christian University, Arizona State University, the University of California at Los Angeles, PNPI - Gatchina, and George Washington University. Tests of rates with nuclear targets of deuterium, carbon, aluminum, and copper were also performed with pion beams, and these measurements will be analyzed by scientists from the University of Colorado. Data were collected at eight momenta between 500 and 750 MeV/c with kaons for E-914. Some of the reactions of interest include $K^-p \rightarrow K_s^0n$, $K_s^0\pi^0n$, $\Lambda^0\pi^0$, $\Lambda^0\pi^0\pi^0$, $\Lambda^0\eta^0$, $\Lambda^0\gamma$, $\Sigma^0\pi^0$, and $\Sigma^0\gamma$. Argonne, the University of California at Los Angeles, Kent State University, and Valparaiso University physicists plan to analyze these data. The K_{e3} tests will be analyzed by the University of California at Los Angeles collaborators, and the $\bar{p}p$ results by Argonne and the University of Maryland scientists.

Argonne physicists were involved in all aspects of the data taking, as well as certain other tasks. For example, they had primary responsibility for the ANL neutron counters located at laboratory angles 4-20°. These counters were crucial for separating the radiative decay reactions $\pi^-p \rightarrow \gamma n$ and $K^-p \rightarrow \Lambda^0\gamma$, $\Sigma^0\gamma$ from backgrounds. One ANL scientist assisted with constructing some hardware for the K_{e3} test. Argonne and Valparaiso University physicists worked together to analyze some of the early July runs with kaon beams, and completed a Crystal Ball note on the results in September. Work has also begun on the analysis of the $\bar{p}p$ data using the single event display to examine individual events. Effort will be more concentrated on data analysis tasks in the near future.

Work also continued on papers describing the results of nucleon-nucleon elastic scattering spin experiments from Saclay. Drafts of two papers written by an ANL physicist on the polarization parameter $P = A_N = A_{00n0} = A_{000n} = A_{00n}$ were sent out to collaborators for their comments. These data were collected at over 30 beam kinetic energies between 1800 and 2800 MeV at c.m. angles near 90° . A search for energy dependent structure in P at two angles showed only a smooth behavior within combined statistical and systematic uncertainties; see Fig. 1. In addition, one new paper was published (“The pp Elastic Scattering Analyzing Power Measured with the Polarized Beam and the Unpolarized Target Between 1.98 and 2.80 GeV,” Nucl. Phys. **A637**, 231 (1998)) and several more are being written by Saclay collaborators.

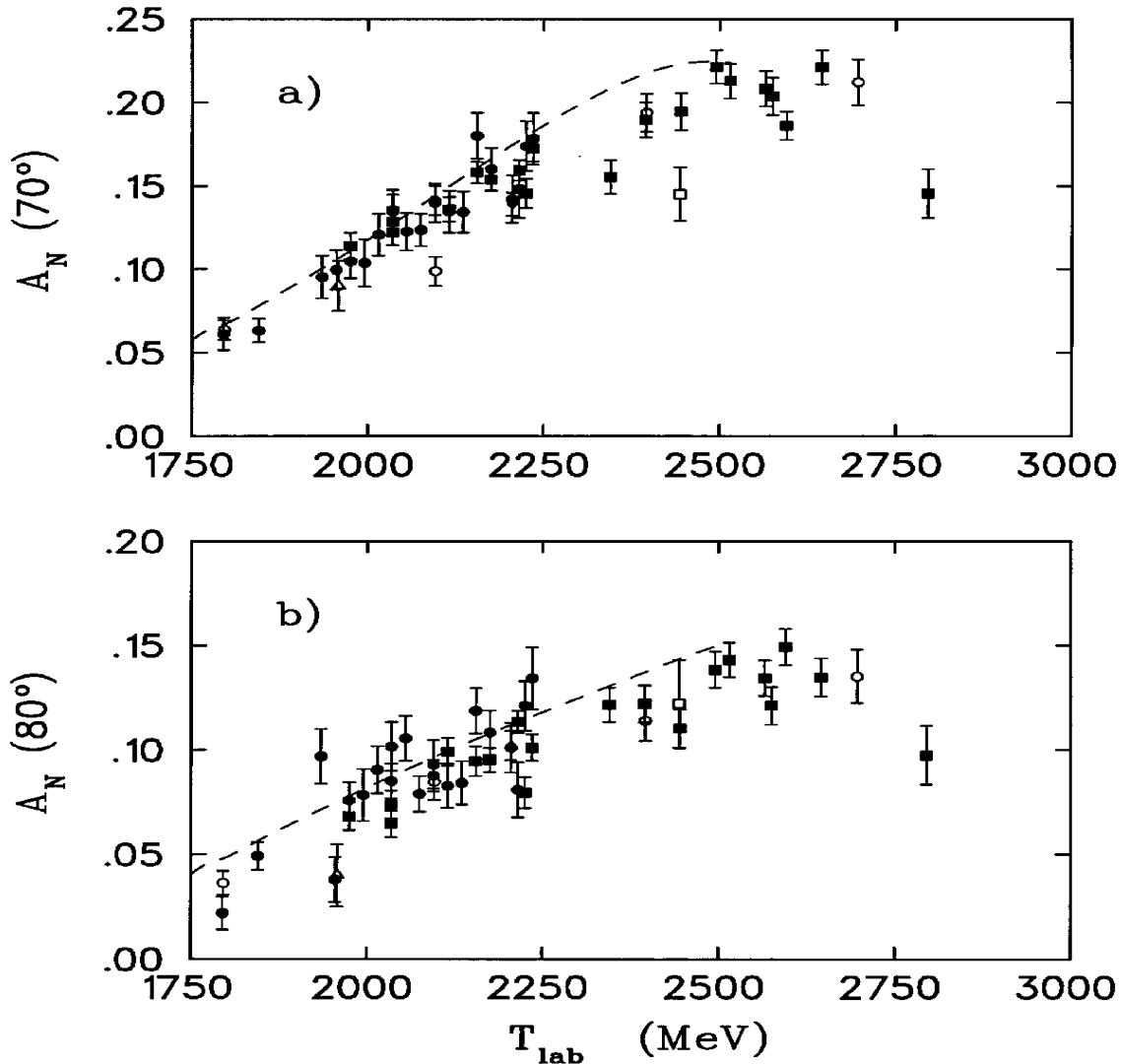


Figure 1. Measured values of the polarization parameter $P = A_N = A_{000n}$ at c.m. angles of 70° and 80° as a function of beam kinetic energy. The solid circles and squares are from recent Saclay measurements, the open circles from previous Saclay data, and open squares, triangles, and diamonds from earlier published data. The dashed curves are for phase shift predictions by R. Arndt, *et al.*

(H. M. Spinka)

I.A.2 Collider Detector at Fermilab

a. Physics Results

In B physics, a lot of effort went into multiple tag CP analysis of $B^0 / \bar{B}^0 \rightarrow \Psi K_s^0$, with Barry Wicklund providing oversight as B physics convener and Larry Nodulman appointed as chief internal reviewer. Public results were prepared for the winter conferences with a paper to follow. Karen Byrum did a trigger efficiency study, which was used by the Toronto group in studies of b jet fragmentation.

In electroweak physics, considerable emphasis was placed on getting a reasonably comprehensive W mass analysis public for the winter conferences, and Andrew Gordon (Harvard) defended his thesis on the electron analysis. Bob Wagner continued as convener for this period. In QCD studies, Steve Kuhlmann worked with Koichi Kurino (Hiroshima) on a study of photon plus charm production using events with a photon and a muon, which resulted in an article submitted. Steve's work with the CTEQ group resulted in a published article, which they regard as the definitive study of parton distributions for Tevatron and LHC physics.

b. Run II Planning

Many of the physics studies being done to plan for Run II were focused by planning for a series of Run II physics workshops at Fermilab. One important topic has been Higgs search possibilities, where Steve Kuhlmann's work on optimizing two-b jet mass resolution, illustrated in Figure 1, has been important.

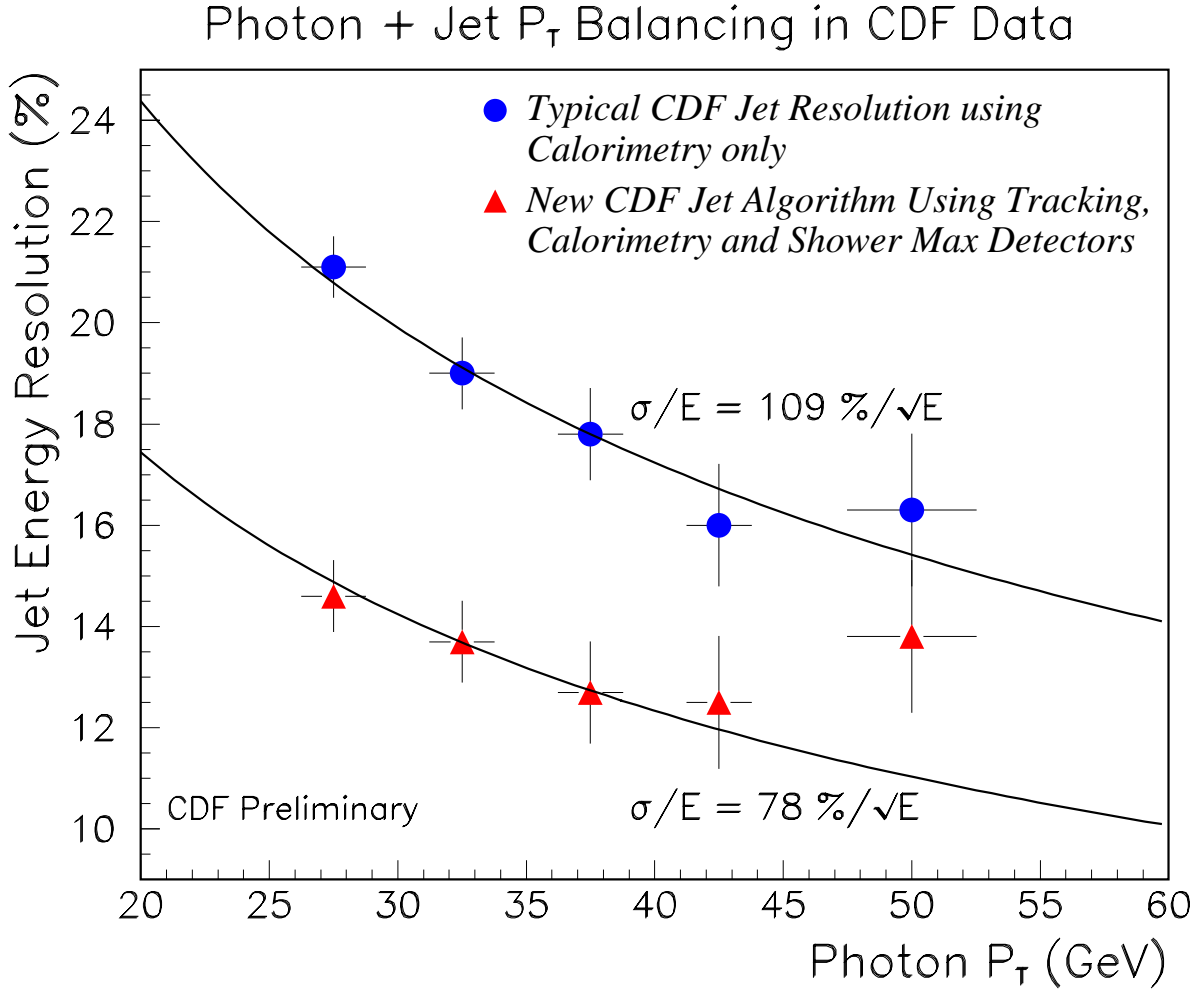


Figure 1. Photon jet balance studies allow the measurement of jet resolution, and the usual calorimeter cluster algorithm is compared to an algorithm using more detailed information including tracks and shower max information.

Within the collaboration there was an internal review of additional possible upgrades not in the baseline upgrade project, and Barry Wicklund served on the internal review committee. One outcome was that the isolation trigger electronics project, developed by Bob Blair and Steve Kuhlmann, was regarded as small enough to simply include in the baseline. The committee and the collaboration decided to propose an inner high voltage single-sided silicon layer ("Layer 00") and time of flight scintillators. A proposal for modifications to allow timing on the central EM PMTs, prepared in part by Bob Wagner, was omitted. Later, mini-plugs for diffraction studies were also added.

Bob Wagner got started on a series of studies attempting to understand and learn how to deal with an apparent nonlinearity in the central EM PMT/base due to diode protection. A cache of spare crack chambers was found, and Steve Kuhlmann verified that the crack

measurements could be useful for improving jet resolution, so a program of replacing dead chambers and upgrading cabling was planned. As an offshoot of studies of triggers and dataset, the group is planning for local datasets to be accessed from the new Linux cluster which Bob Blair and Eve Kovacs have gotten going for us.

(L. Nodulman)

I.A.3 Non-Accelerator Physics at Soudan

a. Physics Results

The measurement of the atmospheric neutrino flavor ratio is of interest due to the apparent anomaly in some reported experiments and the explanation of that anomaly in the context of neutrino oscillations. The double ratio

$$R \equiv \left(\frac{\nu_\mu}{\nu_e} \right)_{data} / \left(\frac{\nu_\mu}{\nu_e} \right)_{MC} \sim \left(\frac{tracks}{showers} \right)_{data} / \left(\frac{tracks}{showers} \right)_{MC}$$

allows a measurement which is independent of an absolute flux or exposure calculation. We have analyzed data from 4.2 fiducial kton-year exposure taken between April 1989 and October 1998. During this period the detector was under construction, starting with a total mass of 275 tons and ending with the complete 963 tons. The goal of the data reduction is to obtain a sample of 'contained events,' defined as those in which no primary particle in the event leaves the fiducial volume of the detector. The fiducial volume is defined by a 20 cm depth cut. Triggered events are passed through a software filter to reject events with tracks entering or leaving the fiducial volume (mostly cosmic ray muons) or events which have the characteristics of radioactive background or electronic noise. Approximately one event per 1500 triggers passes this filter.

The selected events are then double scanned to check containment and to reject background events, using an interactive graphics program. Monte Carlo events equivalent to 5.9 times the exposure of the real data were inserted randomly into the data stream and processed simultaneously with the data events, ensuring that they are treated identically. The neutrinos were generated using the BGS flux.

The lepton flavour of each event is determined by second level scanners who flag them as 'track', 'shower' or 'multiprong.' Tracks which have heavy ionization and are straight are further classified as 'protons.' Proton recoils accompanying tracks and showers are an additional tag of quasi-elastic scattering and are ignored in the classification. Any second track or shower in the event results in a multiprong classification. Results are shown in Table 1. Events with (without) shield hits are labeled "rock" ("gold") events. The quality of the flavour assignment

was measured using the Monte Carlo data. We found that 87% of events assigned as tracks have muon flavour and 96% of showers electron flavour.

The majority of the events classified as contained are due to the interactions of neutral particles (neutrons or photons) produced by muon interactions in the rock around the detector. Calculations show that only a few percent of such events will not have an accompanying charged track traversing our shield, which was placed as close to the cavern wall and as far away from the detector as possible to maximize the probability of detecting the accompanying charged particles. The efficiency of the shield has been measured using cosmic ray muons detected in the main detector. It ranges from 81% during the early data runs before the geometrical coverage was complete to 93% at the end of this data period. Also, 8.9% of Monte Carlo events had a random shield coincidence.

Our large sample of rock events enables us to investigate this potential background by studying the depth distribution of the events in the detector. This allows us to simultaneously measure any backgrounds due to either shield inefficiency or contained events due to neutral particles entering the detector without being accompanied by charged particles in the shield. Neutrino events will be distributed uniformly throughout the detector, while background events will be attenuated towards the center. We define a measure of the proximity of the event to the detector exterior by calculating the minimum perpendicular distance from the event vertex to the detector edge.

In using the depth distribution of the rock events to correct for background, we note that the measured flavor ratio as a function of shield multiplicity is observed to be a constant value of 0.76 ± 0.07 . We then correct the track to shower ratio in the data by fitting the track and shower depth distribution to a sum of those in the rock events and Monte Carlo, constraining the flavor ratio of the rock events to its observed value. The result of the fit gives the corrected neutrino induced rate of 83.6 tracks and 119.7 showers. From this we calculate $R = 0.66 \pm 0.11$, where the error includes the statistical error on the data, the statistical error on the Monte Carlo, and the error on the fit.

Table 1: Classifications for the Contained Events Before Corrections

	<i>Track</i>	<i>Shower</i>
Data: gold	105	159
Background corrected "ν"	83.6	119.7
MC	847	805

If the low value of R is the result of neutrino oscillations, the L/E distribution will be sensitive to Δm^2 . The ability to identify an oscillation signature in an L/E distribution is mainly limited by the measurement of the incident neutrino direction. The neutrino directional measurement is smeared by detector resolution, target Fermi motion, and the failure to image all final state particles. We have found that by placing energy cuts on the data, we can obtain a subsample of events which have the potential for good directional measurement, and hence better sensitivity to oscillation parameters. In Soudan 2, the identification of a recoil proton greatly enhances the ability to identify the neutrino direction. The cuts that isolate this sample are:

- ***Tracks and Showers***

$p_{lept} > 150 \text{ MeV}/c$ if a recoil is present
 $p_{lept} > 600 \text{ MeV}/c$ if no recoil is present

- ***Multiprongs***

$E_{vis} > 700 \text{ MeV}/c$
 $P_{vis} > 450 \text{ MeV}/c$
 $p_{lept} > 250 \text{ MeV}/c$

Because it has the highest statistics with the lowest systematic error, the quasielastic sample is the best sample with which to make the hypothesis test, "*Is there an atmospheric neutrino anomaly?*" The high resolution sample includes about 40% of the quasi-elastic events, but also most of the high energy multiprongs. This sample is preferable to use for neutrino oscillation parameter measurements, which depend on L/E resolution. The zenith angle distribution of the high resolution sample is shown in Figure 1. The ν_μ deficit is clearly seen at all zenith angles.

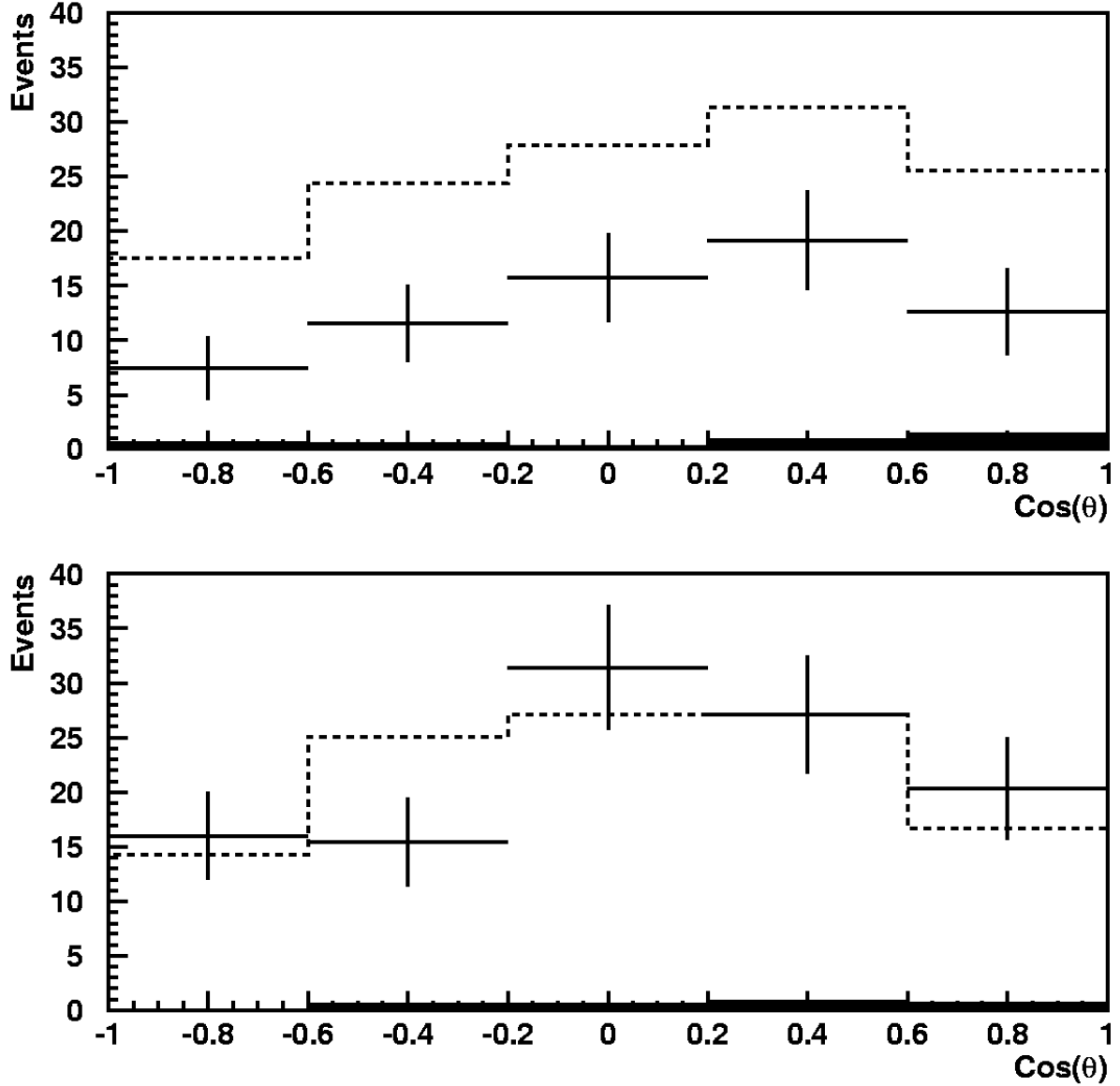


Figure 1. The zenith angle distribution of the data (points), neutrino Monte Carlo without oscillations (dashed line) and the rock background (shaded). The upper curve is for ν_μ events and the lower curve for ν_e 's. The rock and Monte Carlo curves are normalized to the data.

For the high resolution sample the flavor ratio is $R = 0.52 \pm 0.09$. This lower value of the ratio is consistent with our value from the quasi-elastic sample, but is inconsistent with the possible value 0.75 at 90% CL. This value implies a higher value of Δm^2 just because neutrinos from both sides of the earth have to be contributing to the ν_μ disappearance. This conclusion is born out by the L/E fits.

In Figure 2, we show the L/E data for both ν_μ and ν_e without oscillations. In Figure 3, we show the ν_μ data with oscillation fits for maximal mixing and $\Delta m^2 = 10^{-3} eV^2$ and $5.0 \times 10^{-3} eV^2$. In Figure 4, we show the ν_μ data with a oscillation fits for maximal mixing and $\Delta m^2 = 1.1 \times 10^{-2} eV^2$ and $10^{-1} eV^2$. $\Delta m^2 = 1.1 \times 10^{-2} eV^2$ represents our best fit, but the value of χ^2 for larger mass values does not give a bad fit. However, values of Δm^2 below $10^{-3} eV^2$ are ruled out.

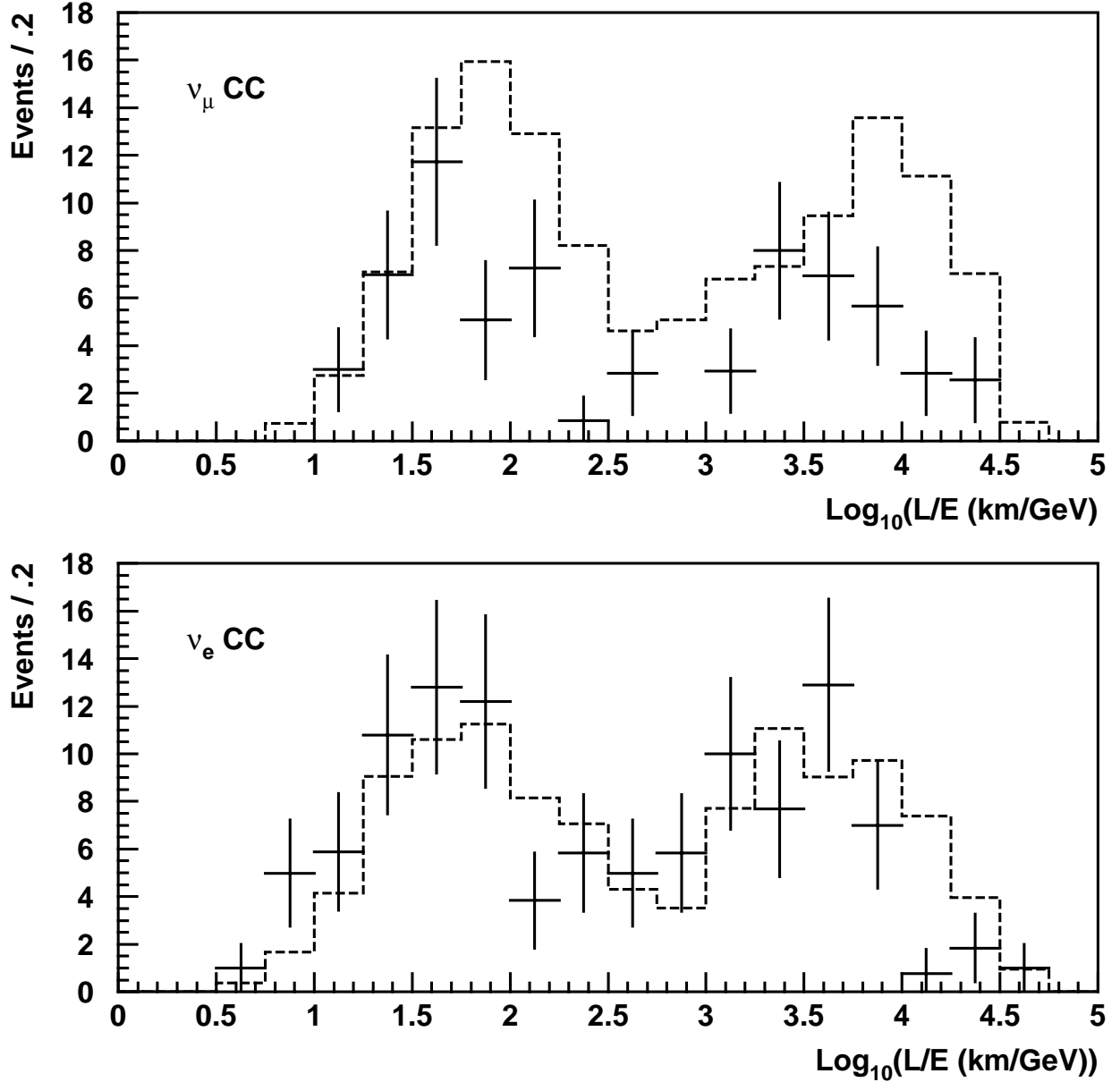


Figure 2. L/E distributions for $\nu_\mu CC$ and $\nu_e CC$ background subtracted data (crosses) and the Monte Carlo expectation without oscillations (dashed histogram). The MC is normalized to 4.2 kiloton-years data.

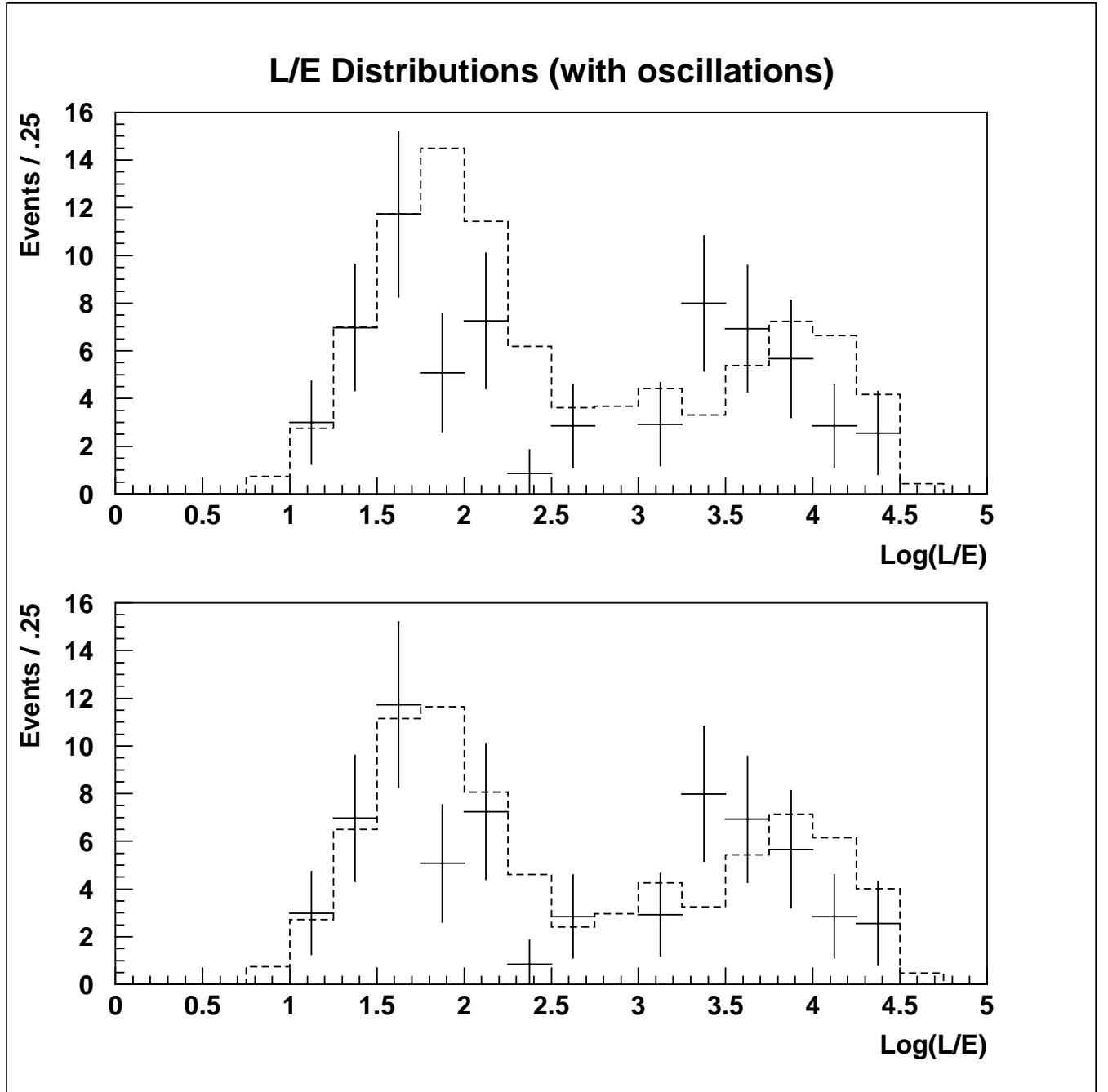


Figure 3. L/E distribution for ν_μ background subtracted data with Monte Carlo expectation for $\Delta m^2 = 1.0 \times 10^{-3} \text{ eV}^2$ (top) and $\Delta m^2 = 5.0 \times 10^{-3} \text{ eV}^2$ (bottom).

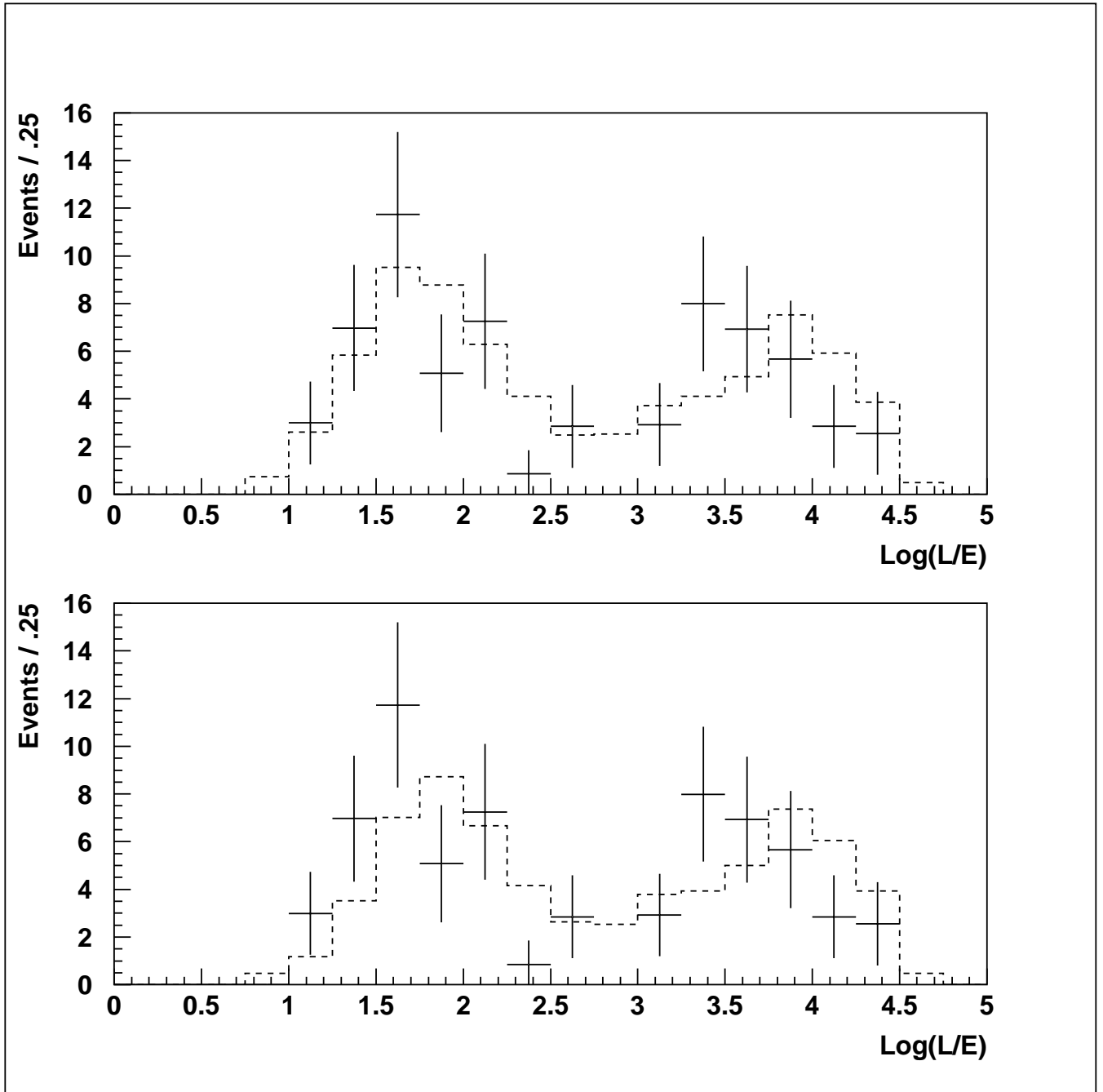


Figure 4. L/E distribution for ν_μ background subtracted data with Monte Carlo expectation for $\Delta m^2 = 1.1 \times 10^{-2} \text{ eV}^2$ (top) and $\Delta m^2 = 1.0 \times 10^{-1} \text{ eV}^2$ (bottom). $1.1 \times 10^{-2} \text{ eV}^2$ is our best fit for $\sin^2(2\theta) = 1.0$.

b. Experimental Apparatus, Operation and Maintenance

Argonne physicists continued to make substantial contributions to the maintenance and operation of the detector. Major activities included ongoing improvements of detector and electronics performance. Argonne physicists also continued the development of software to make use of dE/dx information from the detector.

c. Planning Activities

The Soudan group plans to run the detector for nucleon decay, atmospheric neutrino and other cosmic ray studies until an exposure of 5.0 kt-year fiducial volume is achieved. After that, the Soudan detector will become an integral part of the MINOS long-baseline neutrino oscillation experiment. The progress on that project is described elsewhere in this report.

(M. C. Goodman)

I.A.4 ZEUS Detector at Hera

a. Physics Results

Five papers were published in this period and four more manuscripts were submitted for publication.

i) High E_T Inclusive Jet Cross-Sections in Photoproduction at HERA

Inclusive jet differential cross sections for the reaction $e^+p \rightarrow e^+ + \text{jet} + X$ with quasi-real photons have been measured. These cross sections are given for the photon-proton center-of-mass energy interval $124 < W < 277$ GeV and jet pseudorapidities in the range $-1 < \eta^{\text{jet}} < 2$ in the laboratory frame. The results are presented for three cone radii in the $\eta - \phi$ plane, $R = 1.0, 0.7, 0.5$. The measured cross section $\sigma(R)$ is consistent with a linear variation with R , see Figure 1. The results of leading-order (LO) and next-to-leading order (NLO) calculations of $\sigma(R)$, which are performed at the parton level, for different values of the renormalization and factorization scales μ are shown in the inset of Figure 1. The LO predictions do not depend on R since there is only one parton per jet and show a large variation with μ . NLO calculations give the lowest non-trivial order R -dependent contributions to the jet cross sections and the μ dependence is largely reduced. The slope of $\sigma(R)$ in the NLO calculations with $\mu = E_T^{\text{jet}}/4$ is closest to that of the measured cross section. In addition to the uncertainty coming from the choice of μ , the predictions are affected by the value of R_{SEP} , an ad-hoc parameter introduced to simulate the experimental jet algorithm. In Figure 1 QCD

calculations for two values of R_{SEP} show a variation of about 20%. Within both the experimental and theoretical uncertainties the results appear to be in reasonable agreement.

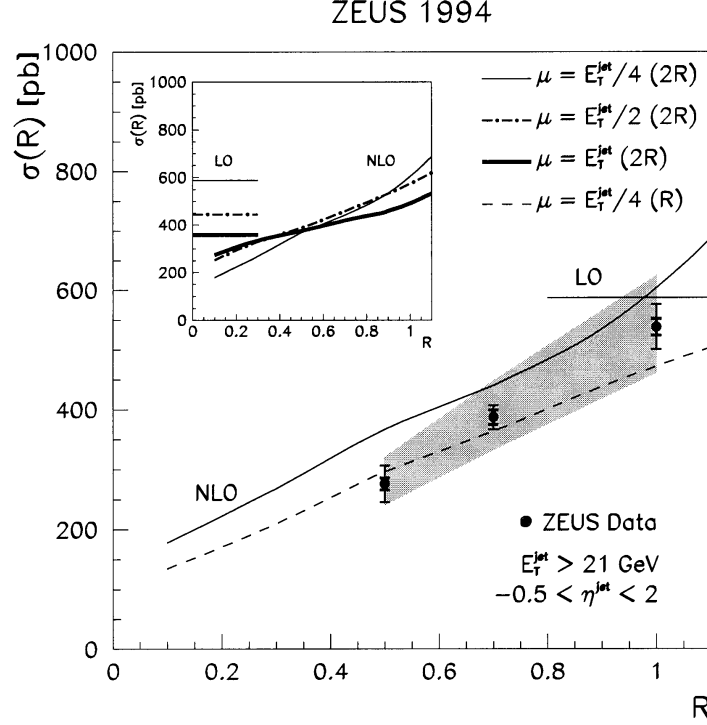


Figure 1. Inclusive jet production cross section, $\sigma(R)$, as a function of the jet cone radius R for $E_T^{\text{jet}} > 21 \text{ GeV}$. The shaded band displays the uncertainty due to the absolute energy scale of the jets. LO and NLO calculations using GS96 (CTEQ4) parametrizations of the photon (proton) parton distributions are shown.

ii) Measurement of Three-jet Distributions in Photoproduction at HERA

The cross section for the photoproduction of events containing three jets with a three-jet invariant mass of $M_{3j} > 50 \text{ GeV}$ has been measured. The three-jet angular distributions are inconsistent with a uniform population of the available phase space, see Figure 2. However, they are well described by both parton shower models and NLO pQCD calculations.

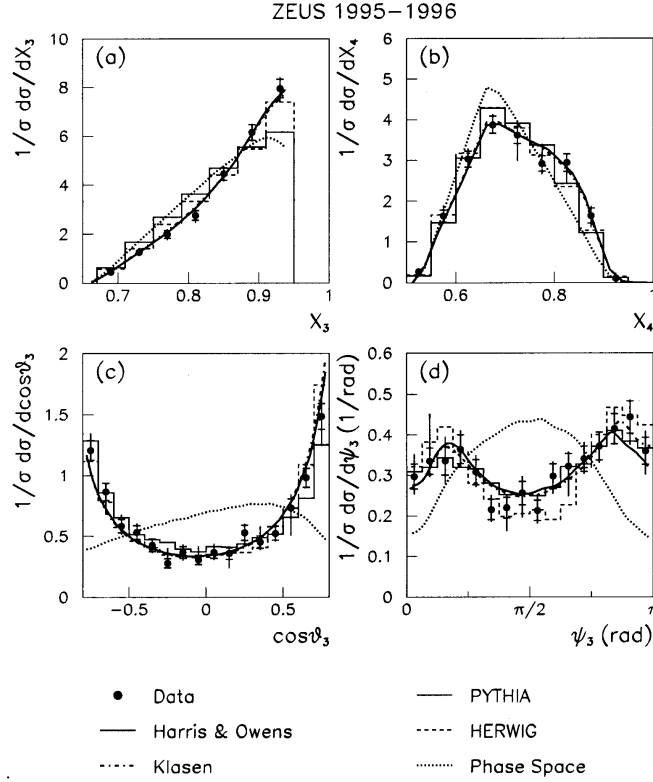


Figure 2. Distributions of the energy sharing quantities, X_3 and X_4 , are shown by the black dots in (a) and (b), respectively, and the distributions of the $\cos\theta_3$ and ψ_3 are shown in (c) and (d). The fixed order pQCD predictions are shown by the thick solid and dot-dashed lines and the parton shower model predictions are shown by the thin solid and dashed histograms. The phase space distribution of three jets is indicated by the dotted line.

iii) Diffractive Dijet Cross-sections in Photoproduction at HERA

Differential dijet cross sections have been measured for photoproduction events in which the hadronic final state containing the jets is separated with respect to the outgoing proton direction by a large rapidity gap. The measurement of the cross section as a function of β^{OBS} , the fraction of the pomeron momentum participating in the hard scattering, is shown in Figure 3. For the selected region of phase space, the measured cross section $d\sigma/d\beta^{\text{OBS}}$ increases as β^{OBS} increases. This result shows that there is a sizeable contribution to dijet production from those events in which a large fraction of the pomeron momentum participates in the hard scattering. QCD based models assuming different pomeron parton distribution adequately reproduce the measurements.

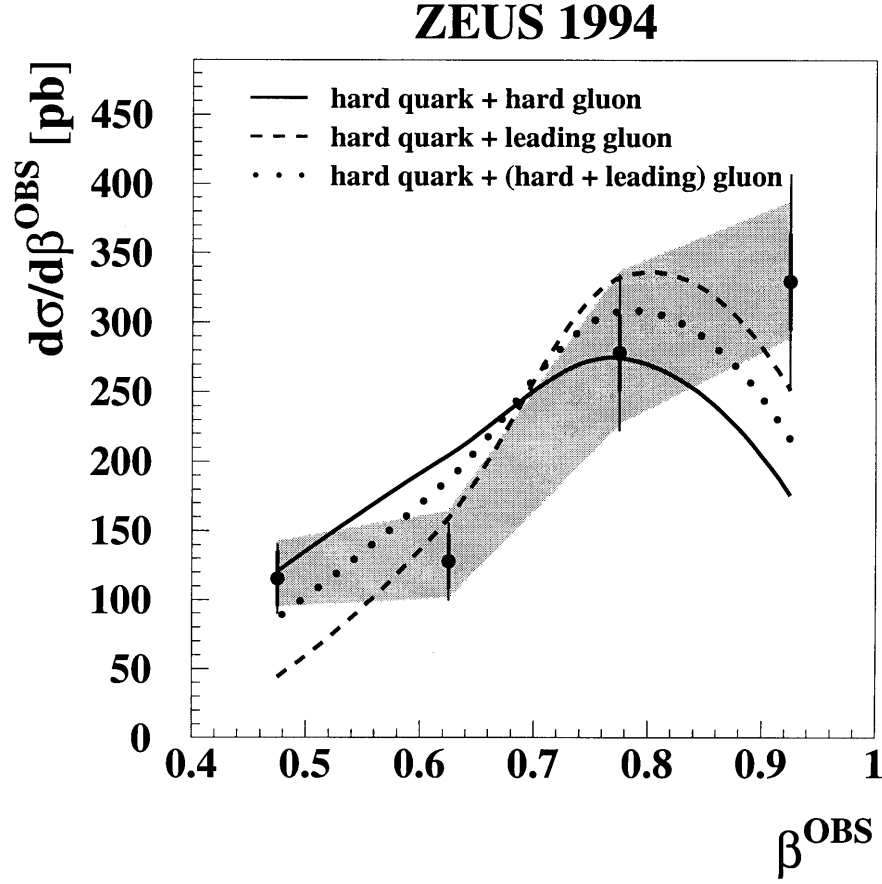


Figure 3. Measured dijet cross section $d\sigma/d\beta^{\text{OBS}}$ integrated over $E_T^{\text{jet}} > 6$ GeV and $-1.5 < \eta^{\text{jet}} < 1$. The shaded band represents the uncertainty due to the absolute energy scale of the jets. For comparison, the results of QCD fits, which have been obtained by an integration over the same bins as for the data, are presented as smooth curves. The fits have been performed using different functional forms for the quark and gluon components of the pomeron.

iv) Measurement of Elastic Upsilon Photoproduction at HERA

The photoproduction reaction $\gamma p \rightarrow \mu^+ \mu^- p$ has been studied and the Υ meson has been observed for the first time in this type of reaction. The sum of products of the elastic $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ cross sections with their respective branching ratios is determined to be $13.3 \pm 6.0(\text{stat.})_{-2.3}^{+2.7}(\text{syst.})$ pb at a mean photon-proton center of mass energy of 120 GeV. The measured cross section is above the prediction of a QCD inspired calculation by L. Frankfurt, *et al.*

v) *Search for Selectron and Squark Production in e^+p Collisions at HERA*

We have searched for the production of a selectron and a squark in the direct decay into the lightest neutralino in the framework of supersymmetric extensions to the Standard Model which conserve R-parity. No evidence for the production of supersymmetric particles has been found in a data sample corresponding to 46.6 pb^{-1} of integrated luminosity. Upper limits on the product of the cross section times the decay branching ratios are expressed as excluded regions in the parameter space of the Minimal Supersymmetric Standard Model, see Figure 4.

b. HERA and ZEUS Operations

After the highly successful run of 1997, the machine shut down in November to install the remainder of the new vacuum pumps necessary for electron operations. The installation was completed in June and no leaks were found. The electron run started in August 1998 and, by the end of the year, the machine delivered collisions with an integrated luminosity of 8.1 pb^{-1} .

The ZEUS collaboration took data with several newly installed components:

- *The Barrel Presampler.* With the completed installation of the Barrel Presampler, the entire high resolution calorimeter is covered with preshower detectors.
- *The Forward Plug Calorimeter.* This new calorimeter required in addition the installation of a new beam pipe with a significantly reduced diameter. The calorimeter covers the very forward region.
- *The Forward Hadron-Electron Separator (FHES).* The FHES will provide a powerful tool to identify the scattered electrons of very high Q^2 events and to identify prompt photons in the forward region.
- *The Position Detector for the Forward Neutron Calorimeter.* This addition will improve our understanding of the geometrical acceptance and, thus, lead to the reduction of systematic errors.

ZEUS 94-97

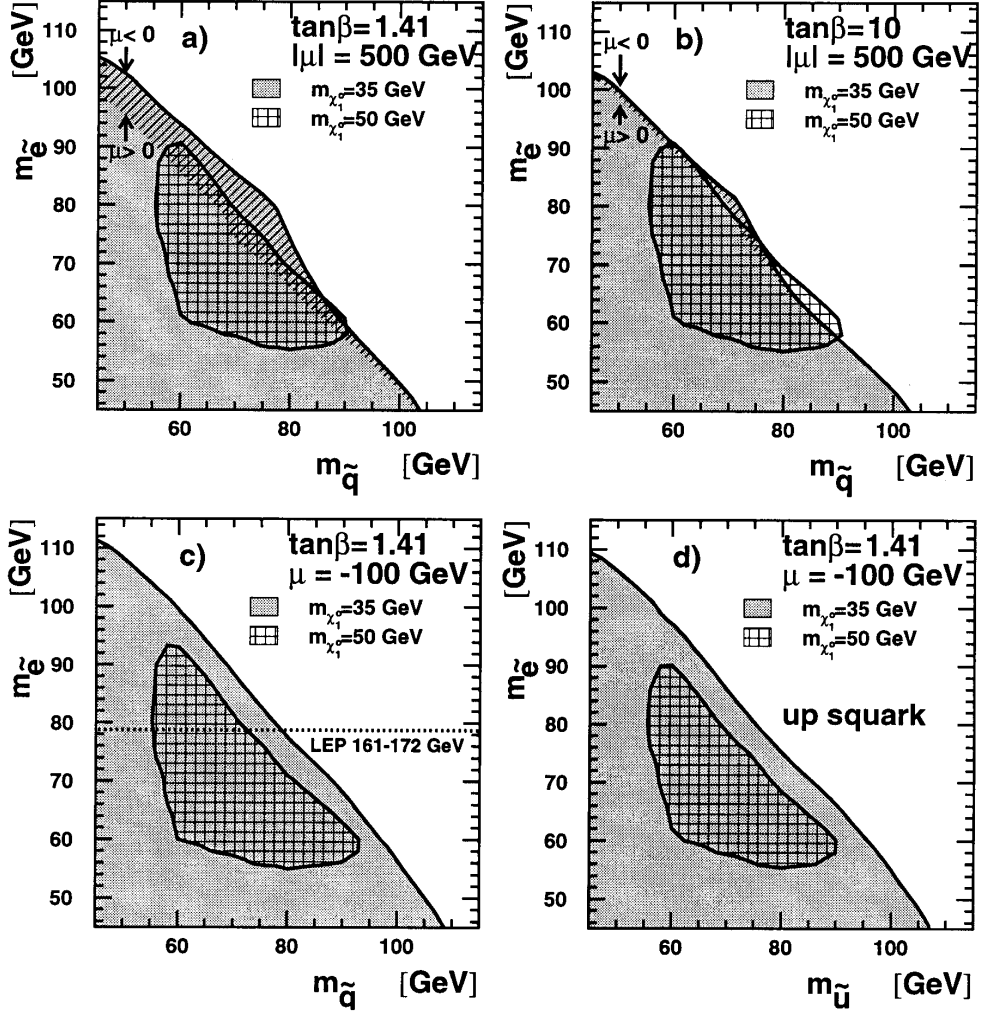


Figure 4. Excluded regions at the 95% CL in the plane defined by the selectron and squark mass, for $m_{\chi_1^0} = 35$ GeV (grey area) and $m_{\chi_1^0} = 50$ GeV (double-hatched area). In a) ($\tan\beta = 1.41$) and b) ($\tan\beta = 10$), the limits are for $|\mu| = 500$ GeV. For $\mu > 0$ GeV, the excluded region includes also the single-hatched area. The limits obtained for $\mu = -100$ GeV and $\tan\beta = 1.41$ are shown in c), where LEP limits on $m_{\tilde{e}}$ are also given. The limits for the up squark alone, for the same values of μ and $\tan\beta$, are also shown in d).

(J. Repond)

I.A.5 BNL Polarized Experiments

The main activities were data analysis and preparation of papers for Experiments E880 and E925. There was also ongoing discussion of the DAQ methods to be used in the upcoming runs of E880, E925, and E950. There was consultation on the design of the Hydrogen target for the next run of E925 and preparation of electronics, magnetic shielding, surveying, etc..

During the joint run of E880 and E925 late last year, a new depolarizing resonance was discovered in the AGS. This forced us to run E925 at a slightly lower momentum than planned, 21.7 GeV/c rather than near 23 GeV/c. This resonance was investigated by mapping out the response in terms of machine energy the horizontal closed orbit, the vertical tune, and the timing and strength of the RF dipole. The RF dipole was used to force a complete spin flip at some intrinsic resonances to avoid depolarization.

These data were analyzed primarily by Mei Bai, a graduate student at Indiana, who is supported jointly by ANL HEP. It was found that this is a new kind of resonance, which depends on the 9th harmonic of the horizontal closed orbit distortion when near a sideband of another strong resonance. It should be possible to suppress it with harmonic closed orbit correctors. A rough draft of a paper describing the new resonance and the analysis was written.

The analysis of the pion inclusive asymmetry data from E925 was continued in great detail by A. Vasiliev of ITEP, who did most of the analysis at ANL HEP during the fall. Because the inclusive proton cross section is about 5 times larger than inclusive pion production at $X (>.7)$ in our P_t range ($>.7$) the analysis concentrated on the cuts utilizing both the Cherenkov ADC and the time of flight TDCs to separate the pions from protons. There was also analysis of the cross section of π^+ and π^- from the Carbon target in order to be sure that systematics were understood. A paper on all the analysis of this pion inclusive asymmetry experiment is being prepared.

(D. Underwood)

I.B. EXPERIMENTS IN PLANNING OR CONSTRUCTION

I.B.1 Polarized-Beam Experiments for a RHIC Polarimeter

While we are no longer involved in the construction of the STAR Barrel calorimeter, we are still interested in the spin physics. We have close ties to a group at the Indiana Cyclotron facility who are proposing the Endcap calorimeter to NSF for funding. The Endcap calorimeter is essential for the coverage at large rapidity which maps to both lower and

higher x than the Barrel calorimeter can cover. This coverage is essential for studying the portion of the proton spin carried by gluons.

If this NSF proposal is approved, we hope to participate in the Endcap through DOE NP Medium Energy Funding.

Argonne was also a participant in the ongoing studies of what do to about a RHIC polarimeter.

(D. Underwood)

I.B.2 MINOS-Main Injector Neutrino Oscillation Search

The MINOS experiment is designed to search for neutrino oscillations with a sensitivity significantly greater than has been achieved to date. The phenomenon of neutrino oscillations allows the three flavors of neutrinos to mix as they propagate through space or matter. The MINOS experiment is optimized to explore the region of neutrino oscillation parameter space (values of the Δm^2 and $\sin^2(2\theta)$ parameters) suggested by previous investigations of atmospheric neutrinos: the Kamiokande, IMB, Super-Kamiokande and Soudan 2 experiments. The study of oscillations in this region with a neutrino beam from the Main Injector requires measurements of the beam after a very long flight path. This in turn requires an intense neutrino beam (produced by the new Fermilab Main Injector accelerator) and massive detectors. The rates and characteristics of neutrino interactions are compared in a “near” detector, close to the source of neutrinos at Fermilab, and a “far” detector, 730 km away in the underground laboratory at Soudan, Minnesota. The neutrino beam and MINOS detectors are being designed and constructed as part of the NuMI (Neutrinos at the Main Injector) Project at Fermilab.

The MINOS detectors are iron-scintillator sandwich calorimeters, with toroidal magnetic fields in their thin steel planes. The combination of alternating active detector planes and magnetized steel absorber planes has been used in a number of previous neutrino experiments. The MINOS innovation is to use scintillator with sufficiently fine transverse granularity (4-cm wide strips), so that it provides both calorimetry (energy deposition) and tracking (topology) information. The 5,400 metric ton MINOS far detector is also much more massive than previous experiments. Recent advances in extruded scintillator technology and in pixelated photomultipliers have made such a detector feasible and affordable for the first time.

During 1998, results from Super-Kamiokande, Soudan 2 and MACRO experiments continue to provide increasing evidence that neutrino oscillations are taking place in just the regions of parameter space that MINOS was designed to explore. This has provided

mounting impetus to go forward with MINOS as expeditiously as possible. One aspect of the Super-Kamiokande data has raised the possibility that Δm^2 is lower than earlier thought, perhaps a bit below $10^{-3} eV^2$. MINOS will not be as sensitive to oscillations at such low values of Δm^2 , so we have put a major focus on studying how our reach can be increased by going to a lower energy beam. The projected event rate decreases for a lower energy beam, so the increase in sensitivity is not dramatic. However it has been shown that increased sensitivity is possible in just the parameter regions of interest. Data from Super-Kamiokande in late 1998 has reduced concerns that the neutrino oscillation parameters will be outside of the MINOS region of sensitivity.

The major activity of the MINOS collaboration, and the Argonne MINOS group during the last half of 1998 was the preparation of the Technical Design Report (TDR) and the Cost and Schedule Plan (CSP) for the NuMI-MINOS project. These were completed for a Department of Energy Baseline Review of the NuMI Project during the first week of November, 1998. The purpose of the review was to examine the technical, cost, schedule and management planning for NuMI and MINOS. The Committee found that, "it is more desirable than it was even a few years ago to go ahead with a strong long-baseline neutrino oscillation program at Fermilab. MINOS ... is well placed to address this most important issue." An important consequence of passing this review was the go-ahead for preparations for building the new cavity at Soudan. A cross section of the new cavity and its relationship to the existing Soudan cavity is shown in Figure 1.

The second major focus of work by the Argonne MINOS group, after preparation for the NuMI-MINOS baseline review, was the engineering design and prototyping of critical parts of the scintillator detector system. Argonne physicists and engineers serve as NuMI Project Level 3 WBS Managers for the scintillator strip fabrication and for the design and construction of the machines needed to construct scintillator modules. Prototype polystyrene scintillator strips extruded by a commercial supplier, Quick Plastics, were evaluated at Argonne and several variations on the extrusion conditions continue to be tested in order to improve light output and reduce cost. The Argonne group also continued work on a prototype production facility for scintillator "modules" in Building 366. Several modules were produced for testing at Fermilab. Modules are panels of 20 or 28 4-cm wide scintillator strips, which are packaged for easy handling and shipping. During the second half of 1998 the group's work focused on the testing of optical fiber gluing and routing techniques, manifold design, and the development of an automated device for mapping the response of modules using a rapidly moving radioactive source.

Argonne MINOS group members also serve as WBS Level 2 managers for electronics and for far detector installation. During the second half of 1998 they continued to work closely with the Oxford and Rutherford groups to develop the parameters of the baseline electronics design. Responsibility for the design of the electronics system has been divided

between the US and UK groups, with Argonne taking primary responsibility for the front end electronics development. Far detector installation work during this period involved close interaction with the architect engineering firm, CNA Consulting Engineers, which prepared the bid specifications for the new MINOS cavern, including its infrastructure and the detector support structure. The Argonne installation group also continued to work on the design of installation procedures for the detector at Soudan, in close collaboration with the Soudan 2 mine crew and with CNA.

Finally, Argonne physicists have been heavily involved with preparations for MINOS excavation work at Soudan, particularly as it impacts continued operations of the Soudan 2 detector. Data from a series of test blasts early in 1998 were evaluated in order to provide specifications on vibration monitors for the MINOS construction bid. These specifications are not expected to increase the cost or affect the schedule of the MINOS cavern excavation.

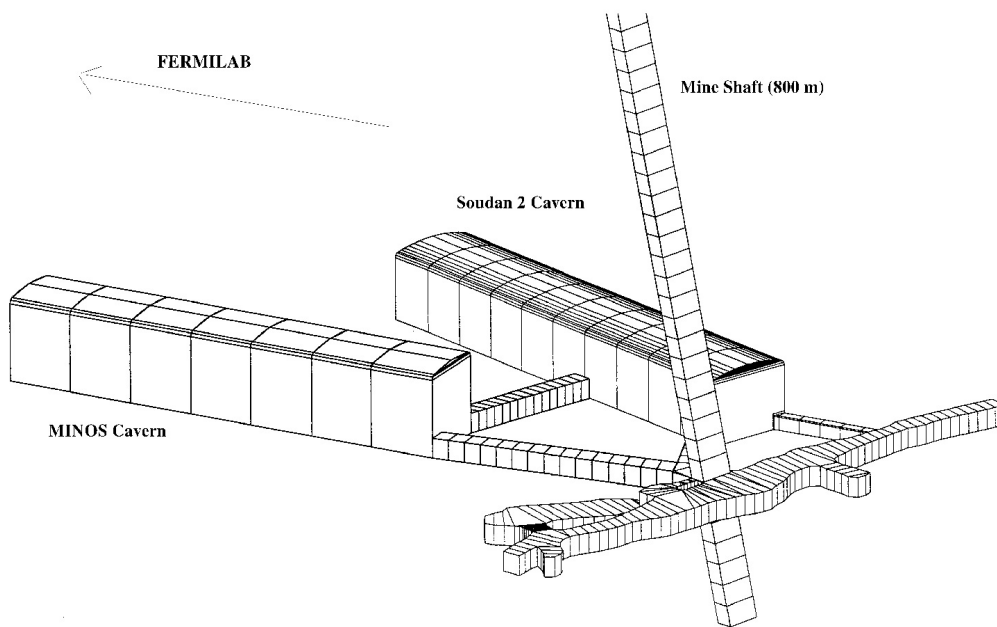


Figure 1. Sketch of the MINOS and Soudan 2 caverns in the Soudan Underground Mine State Park in northern Minnesota.

(M. C. Goodman)

I.B.3 ATLAS Detector Research & Development

a. Overview of ANL LHC Related R&D Programs

The TileCal subsystem realized several key project milestone in the second half of 1998: all 41,000 master-plate plates for the extended barrel calorimeters were stamped, again using the US manufactured die; submodule construction started up in Dubna with construction of the first submodules for the barrel modules; the final design for the main structural support was re-evaluated in depth and construction approval given. Finally, the US Atlas project as a whole was favorably reviewed by a joint DOE/NSF committee.

(J. Proudfoot)

I.C. DETECTOR DEVELOPMENT

I.C.1 CDF Detector and DAQ Electronics Development

a. Run II Project

Shower Max Calorimeter Readout has been a major project for us. Gary Drake did the testing which showed that the production order at Fermilab for the shower max current splitter and ADC ASIC "SMQIE" could finally be placed. He also has charge of the SIM mounting boards "SQUID" for these chips, which have iterated with prototypes and have digital test versions. John Dawson has brought the VME readout boards "SMXR" which interface to the "SMC" cards which house the Squids ready for production. Steve Kuhlmann, Jimmy Proudfoot and Jim Schlereth, working with John and Gary, have put together a system test to develop software for readout and calibration of the whole system as well as for production testing of SMXRs. Karen Byrum has been working with Gary to develop the amplifiers needed for the wire chamber shower max readout, and it seems a quiet and quick enough amplifier can be made which could be put on the SMC input auxiliary boards.

Karen and John have been working with the Michigan group to design the shower max Level 2-trigger bit input. The expertise developed is also being used to design the Level 1 interface to Level 2. Steve, John and Bob Blair have making good progress on isolation trigger electronics now that this has been included in the baseline scope of the CDF upgrade. Bob Wagner and Randy Thurman-Keup have been developing offline software for calorimeter reconstruction with emphasis on electron code.

Randy has been working with Vic Guarino, Larry Nodulman and the central drift chamber "COT" group at Fermilab to develop production tooling for inserting the wire planes and field sheets into the can of the chamber. Two sets of engines were put together, debugged and delivered to Fermilab in time to begin stringing.

Good progress also characterized the muon upgrade, which remains under the oversight of Tom LeCompte.

(L. Nodulman)

I.C.2 ZEUS Detector Upgrade

a. Straw Tube Tracker Readout Electronics

ZEUS is planning to install during the machine shutdown of 2000 a new forward tracking detector based on the straw tube technology. The new detector will consist of 24 layers containing a total of 12,000 tubes. It is expected to greatly improve the detectors capability of measuring high Q^2 neutral current events, of determining charged current event vertices, of tagging heavy flavor decays in the forward direction, and of charged particle tracking in general. The detector is being built by a group of nine institutions, which are part of the ZEUS collaboration, and will partly replace an existing forward tracker of limited usefulness.

The Argonne group took over the responsibility of designing and building the front-end electronics consisting of shapers, discriminators, a multiplexing circuit and a cable driver circuit. The multiplexing is necessary to accommodate the 12,000 channels of the new detector to the 2000-channel readout system of the existing forward detector.

As a first step, Argonne built a prototype board containing the ASDBLR chip developed by the University of Pennsylvania to shape and discriminate the signals and a circuit to drive the standard 42 m signal cable employed by the experiment. The board is used to readout a prototype sector of the new straw tube tracker currently being tested in the DESY test beam.

(J. Repond)

I.C.3 ATLAS Calorimeter Design and Construction

In this period work continued on completion of tooling for the construction of the calorimeter submodules and on review of critical engineering design data. In particular, a re-evaluation of the design of the main support element, the girder, was completed and final

drawings approved for construction. As part of this work we also considered and developed the scheme for the support of the endcap calorimeter cryostats. Finally, substantial effort was spent in developing plans and procedures as a basis for the construction effort. These three areas are addressed in more detail below.

a. Structural Design and Analysis

The calorimeter load analysis was thoroughly reviewed by Tile Calorimeter engineers at the engineering meeting held prior to the September ATLAS week. The results of structural analysis of the girder were reviewed in detail, taking into account seismic, magnetic, and gravitational loads. There was complete consensus on the results, which showed that the impact of the revised cryostat load conditions was negligible at the outer radius connections. However, the calculations showed that the bearing load at the inner radius would increase to about 1400 N/mm. The conclusion of the group is that this will require the bearing surface in this region to be increased by at least a factor of two relative to the front plate for some of these modules. The details of how this will be achieved remain to be determined (although it has been determined empirically that appropriately machined and shimmed master plates are capable of being used to accomplish this). In addition, the maximum stresses in the girder welds occur in the girders directly above the support saddle. In order to achieve an adequate safety margin in these welds, the design of the weld was changed from a fillet to a J weld. The plates at the outer radius of the girder that connect them together were also examined using finite element modeling and hand calculations. The 25mm bolts at this connection were increased to 30mm and additional holes were added to increase the number of pins at the bottom of the calorimeter to accommodate the tensile load in this area (primarily associated with small changes in the cryostat loading). A series of mechanical tests were conducted at CERN to determine empirically the stress/strain characteristic of the welds up to and beyond the maximum loads for which this connection must be designed. Results showed a safety factor of 3 relative to the maximum load and the design has been approved for tendering by the subsystem leader. The procurement of the barrel girders is underway and we anticipate beginning the procurement process for the extended barrel girders at the beginning of 1999.

b. Other Design Work

The design of the hydraulic jack for the front cryostat support was completed and given to Argonne Central Shops for fabrication of a prototype. Due to the holiday, actual construction will begin in January 1999. Other design work of note comprised:

Submodule weld specification. The specification for the welding of submodules was discussed with the European collaborators. A final version of this specification has been agreed upon.

Submodule construction. A draft QC procedure document was completed and distributed to the Tile Collaboration as a basis for a subsystem-wide approach for verification of submodule construction.

Drawing review. Work has also been continuing as part of the ongoing review process of drawings to approve them for production.

c. Calorimeter Construction

The procurement of raw sheet steel and stamping of all 41,000 master plates required for the construction of the extended barrel calorimeters was completed in this period. Approximately 23,000 plates were delivered to submodule assembly sites and the remainder will be shipped in January 1999.

c.1 US Master Plate Production

The procurement of the steel and stamping was completed in mid-December with only one other pause in production when thermal differences between the stored plates and the die caused some dimensions to go out of specification. By the end of December, the University of Chicago had received its full complement of 6,102 plates, ANL had received 6,008 plates (representing all plates required for submodule construction), Barcelona 9,263 plates, and the University of Illinois 2,180 plates. The remainder of the plates will be shipped by the end of January. The stamping die will be temporarily stored at Prague until it has been determined that all of the institutions have successfully received their plates. At that time the die will be shipped back to ANL for storage until the project is complete.

c.2 Master Plate Steel Procurement

The steel for the master plates was supplied by the same Czech steel company that had supplied the steel for the barrel master plates. This insured uniformity of the mechanical and magnetic properties. The same QC protocols were used for accepting steel shipments as were used for the barrel production.

The first 250 tons of steel were shipped to the stamping plant in the Czech Republic on September 7th. Technicians from the Prague group inspected this steel as per the steel specification. A total of 75 pallets of steel out of the 96 delivered were accepted. The remaining 21 pallets were found to be out of specification based on measurements of the first and last plate on the pallet. On September 26th, the Prague group returned to the stamping plant and inspected every plate within these 21 pallets (100 plates per pallet) and recovered approximately 70% of this material. The problem was reported to the vendor and corrected for subsequent deliveries.

c.3 US Master Plate Stamping

During the first half of 1998, the ANL master plate die had been installed in a 1,000-ton press at a company called Tatra in the Czech Republic and used for the production of approximately 40,000 master plates for the barrel calorimeter. This production ceased around June and the die was stored at the Tatra plant until September when an engineering associate and physicist arrived from ANL to observe its re-installation in the press for the production of approximately 42,000 master plates for the extended barrel modules. Measurements were taken of the parallelism of the die surfaces. These were found to be parallel to within .2mm which was deemed to be more than adequate to begin stamping. Six master plates were then stamped and measured on a CMM machine. All of the dimensions on these measured master plates were found to be within specifications and production of master plates was then allowed to begin.

A total of approximately 6,100 plates were stamped during September. During production, QC data was faxed on a daily basis to ANL as part of the contract. In particular, this included the measurements of approximately 40 dimensions on a sample of plates (1 per 600) on a high precision computer-measuring machine. All of the QC data in this period showed that the required specifications had been met. Early in November, after stamping about 13,000 plates from the beginning of production for the extended barrel and the last re-sharpening of the die, the variances from nominal of the location of the holes down the center of the plate started to exceed specification. Analysis of the data suggested that this variation was simply due to thermal affects. However, on the advice of the stamping company, the die was re-sharpened and this variance was eliminated. One physicist and one technician visited the TATRA plant following re-sharpening of the die and verified that the protocols from 6 plates stamped at this time met specification, which they did. During this visit, random samples of raw sheets were also inspected to confirm that they, too, were within specification.

c.4 US Master Plate Shipping

Prior to the beginning of production, arrangements had been made for shipping the master plates from the Czech Republic to Spain and the US. Shipping to the US was handled by American Overseas Transport for ANL and shipments to Spain were directed and paid for by CERN. The steel was shipped on pallets of approximately 80 plates. This represented about 1.5metric tons per pallet. Thirteen pallets were placed in a container.

One minor problem was encountered during shipment of plates from the Tatra plant to the United States. Pallets within the initial shipments of containers were broken and plates were strewn throughout the container. Several of the pallets shipped to the University of Chicago had shifted during shipping and, on some of these, the bands had broken and plates shifted. Much more serious movement occurred in 3 of the 4 containers sent to Argonne, in

which 26 out of a total of approximately 50 pallets had shifted in transit, resulting in many broken bands and serious disarray in the container. In several cases, the pallets were sufficiently unrestrained as to require unloading plate by plate. The off-loading times were also much larger than expected for these containers. This issue was discussed with TATRA and they were requested to increase the number of bands used to fasten the plates together and onto the pallets, as well as to more securely block and brace the pallets in the container. The 26 pallets at Argonne, which were in various states of disarray, were completely re-stacked (manually) and inspected for damage in critical areas (keys and tabs). Although some roughened edges were found on the plates of a few pallets (not considered a problem, as this will be cleaned up in the Timesaver process), only 6 plates damaged beyond reasonable repair were rejected at this time. No further problems were encountered following the changes in banding and blocking of pallets.

d. Submodule Small Components

Several of the components required for submodule construction are the responsibility of our European collaborators. These include:

- Spacer plates from Spain
- Structural adhesive from CERN
- Small keys via CERN
- Spring pins from CERN
- Protective paint via CERN

In the US, we are responsible for fabrication of the weld straps used in the assembly of modules constructed here. This is a joint UTA/ANL task. Weld bar stock was received at ANL and a small number of bars were sent to UTA in November for the performance of fabrication tests in UTA's machine shop prior to committing the full fabrication. UTA machined the first sample of weld bars for standard submodules. The quality and dimensions of these samples were checked at UTA and ANL and found to be satisfactory. All the weld bar material will be shipped to UTA from ANL at the beginning of January 1999. Machining will start around the middle of January and the first shipment to ANL will occur on February 1. Shipments to the other submodule assembly sites in the US will occur shortly thereafter.

e. Module Shipping

An extensive amount of time was spent on the planning of module shipment to and from MSU and CERN. Analysis was carried out on the loads during shipping and arrangements for getting modules into the MSU laboratory. An industrial crating company was found that put together a proposal for blocking and bracing modules into containers. This latter area will be pursued more extensively in 1999.

f. Building Preparations in 366

Production of submodules and modules will occur in Building 366. Work continued in this building in order to prepare for production. A general cleanup of the building occurred in which older equipment from previous experiments was either discarded or moved to storage. In addition, an existing truck loading dock was modified to allow a simple transfer of materials into the building (the height of the dock was originally mismatched to the height of a standard container or flatbed truck). This dock was completed by the end of September, in time to be used to take delivery of master plates.

The equipment in the building was re-arranged to make room for the Atlas production line. Gantry cranes that would be used for production were set up and rails laid on the floor for guiding them. The existing stacking fixture, welding and inspection tables, and module assembly fixture were moved to be in alignment with the gantries. Modifications to the enclosure where submodule production will occur have also been made. In preparation for the installation of a roll-up door required to provide access for a gantry crane, wiring and other fixtures on the affected wall were removed and re-routed. In addition, a submodule storage rack was constructed that was capable of storing 5 modules worth of completed submodules (50 submodules in total).

In the summer of 1998, Argonne decided to use the identical glue dispenser that was used in Europe and ordered one in a common procurement through CERN. Some design work was required to detail the associated gluing table and control system to US norms. An automated glue machine was also fabricated during this period that was also based upon the machine designed by our collaborators in Spain. Again, the Spanish design required modification to accommodate US standard sizes for structural tubing and motors and controllers that were already available at ANL. The hardware for this system was fully assembled in this period. The control software will be written and debugged in early 1999 to allow startup of submodule construction as soon as spacer plates are delivered from Europe.



Figure 1. Commercial (Timesaver) machine used for plate preparation for gluing.

A decision was made in August to use a commercial abrading and washing system to prepare master and spacer plates for gluing. Two companies were identified as being able to supply a machine that met the requirements of deburring the plates while creating a surface finish that was optimal for gluing. This machine also had to have the capability to completely clean the plate of residual oils from the stamping process so that the plates may be immediately stacked into submodules. Following evaluation of the machines provided by these vendors and discussions with Timesaver on some aspects of the machine being proposed as possible areas in which costs could be reduced without compromising performance, the Timesaver system was selected. Various simplifications were made to the original proposed machine such as the elimination of touch screen computer controls and automatic lubrications systems. This significantly reduced the overall price of the machine. Delivery was taken in October and the machine installed and set up in the building (Fig. 1). Both other groups involved in submodule construction plan to buy this system also.

Due to changes in the design of the girder (in particular the bolt hole pattern) some changes to the exiting module assembly based were required. These were completed in this period and the modified based mounted and aligned in its final location.

(V. Guarino and J. Proudfoot)

g. Calorimeter Instrumentation and Testing

A variety of tasks associated with module instrumentation and testing were begun and continued during this period.

There was work on a mini-submodule to be instrumented for tests at Argonne, and a light-tight box for it. The purpose of this mini-submodule is to gain experience in both the mechanical and instrumentation aspects, and to have a platform for testing QA procedures. The mini-submodule was stacked, though the spacers used were from the prototype program and therefore not of the same dimension as planned for production. Fiber profiles were provided by the Lisbon group. The scintillators used were from a pre-production run. Portions of the fibers to be used in the instrumentation were aluminized at Fermilab.

Work began on the conversion of space previously used for CDF development to space for Atlas TileCal instrumentation. As part of this work, we initiated the design of a light-tight tent. Criteria used were that the tent be fireproof, provide two cable paths, have the ability to be raised between the building light fixtures, and provide ease of use.

Two ANL physicists made a visit to MSU primarily for discussion of QA methods. There was also discussion of compatibility of MSU and ANL module support and moving devices and logistics of moving modules in and out of instrumentation areas. The QA discussions with MSU included comparison of response to radioactive source vs. LED. This could be used in two different ways: for quantitative test of extended barrel module and for evaluating methods of checking fiber routing. We agreed to do the comparison at ANL in early 1999.

We provided ANL data on long-term optical properties of fiber under stress to CERN TileCal management for support in writing specifications for fiber procurement.

At the time of the November ATLAS meeting, there was much discussion with MSU regarding simple statistical models of fiber quality distribution. There was also continuing interaction with MSU and CERN on issues such as fiber procurement and QA checklists.

Work continued on the design and some prototypes of a source drive for ATLAS and MINOS.

(D. Underwood)

h. Test Beam Program

The thrust of the last half of 1998's effort was to verify in the testbeam run that the optics and electronics were of sufficiently good quality for production. The barrel Module 0

was instrumented with good quality scintillator and fibers with varying properties ranging from different manufacturers to the addition of UV-absorbing chemicals. Furthermore, the electronics were changed from the old FERMI system to a prototype of the on-board digitizers during the last week of the testbeam run. Data was taken in June and July of 1998.

HEP staff took an active part in the analysis of the June/July 1998 data. Most of the activity consisted of actually certifying the data for use by the rest of the collaboration. A major problem in the run was the failure of many of the FERMI ADCs. The failure manifested itself in at least two ways: timing shifts and dropping bits. These problems were intermittent but there also were cases of ADC replacement necessitating different calibration. Thus, a big part of the analysis consisted in flagging bad channels for each and every run. This was done by HEP staff studying the laser data, looking for large changes in slopes (dropped bits) and changes in the position of the peak sample. Bad channels were flagged for the software people and the appropriate corrections were made for production ntuples.

The response and resolution are shown in Figs. 2 and 3 for the minus side runs. Electrons incident at a variety of η s and at 90 degrees enabled us to find the all-important scale of the calorimeter. Response at 100 GeV ranges from 77 to 87 and there is a falloff of about 7% going down from 20 to 5 GeV. Corrected resolutions are about $25\% \sqrt{E}$. The apparent lack of linearity at the low momenta can also be seen from Fig. 2. This effect is verified by other analyses, and we recommended that low-beam momenta be measured next year as part of our testbeam program.

(R. Stanek)

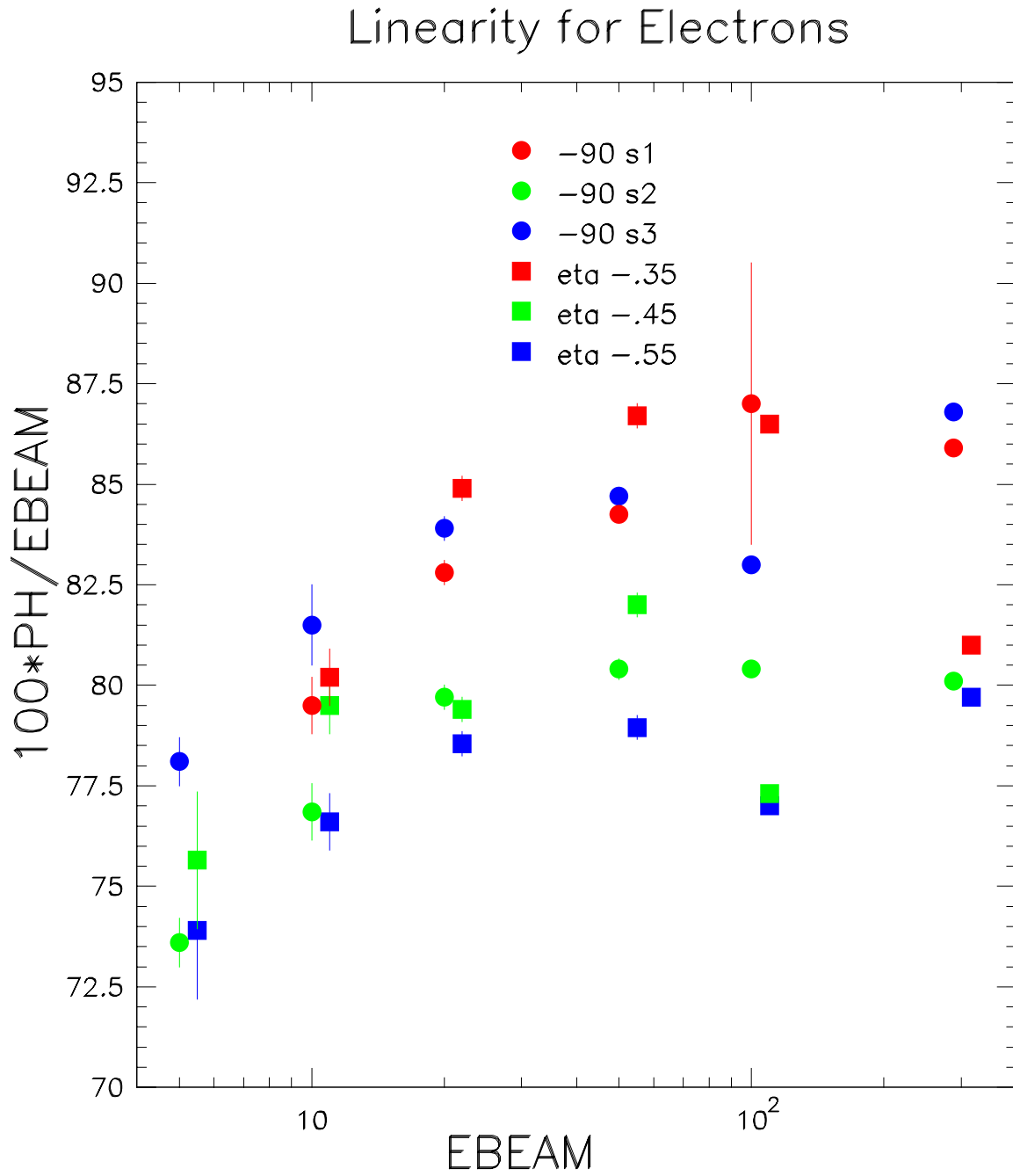


Figure 2. Mod0 response to electrons in June/July 1998 testbeam run. Also shown is resolution normalized to $\tan(\eta)$.

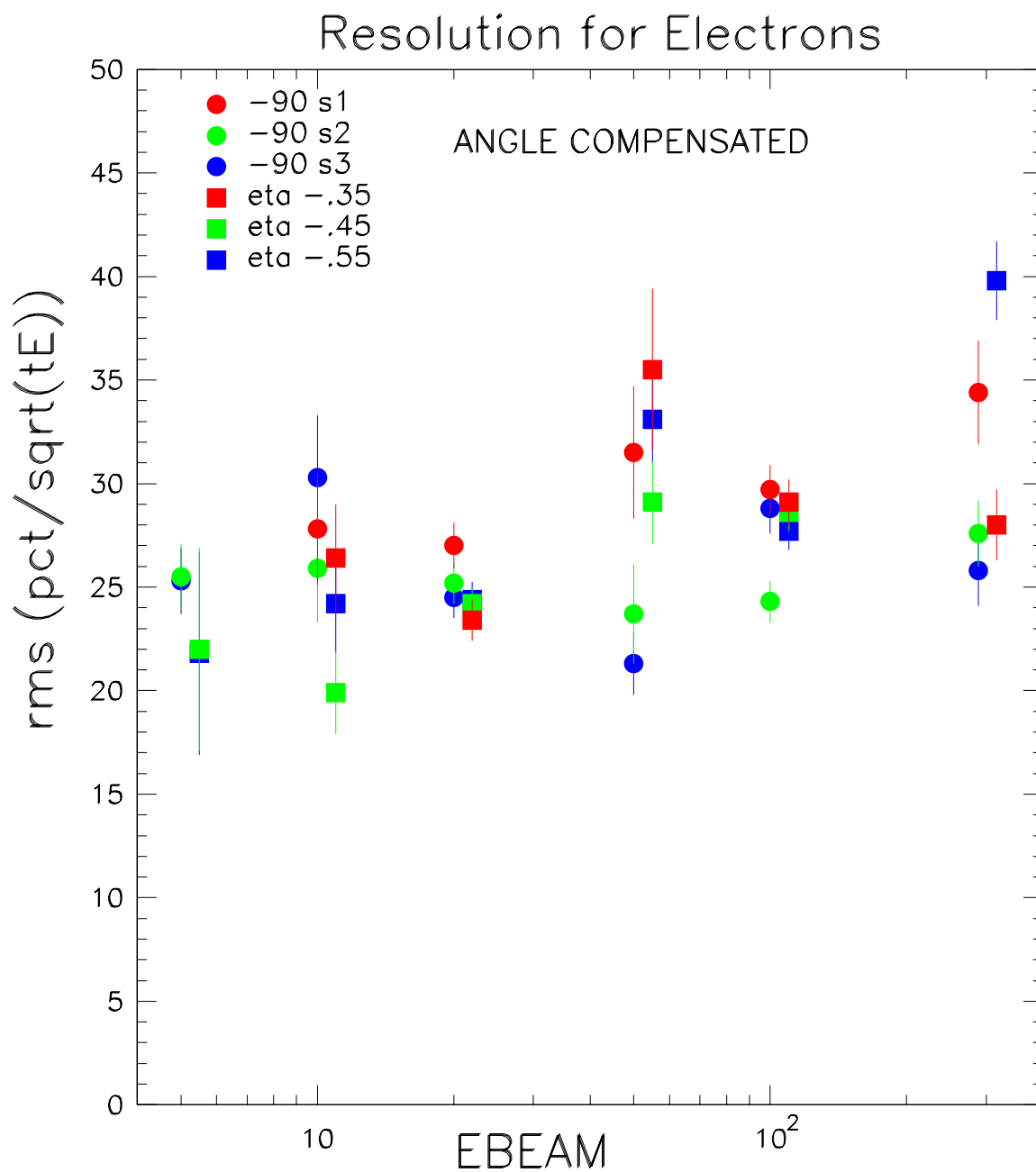


Figure 3. Mod0 resolution for electrons in June/July 1998 testbeam run. Also shown is resolution normalized to $\tan(\eta)$.

i. Project Management and Planning

Regular reports on technical progress were provided to the US Atlas management and form part of the general monitoring of cost and schedule. In addition, one physicist in the group has taken on the task of monitoring the QC data for the entire TileCal subsystem and one physicist has the responsibility for coordinating the TileCal testbeam area and program.

(J. Proudfoot)

I.C.4 MINOS Detector Development

During the second half of 1998, the Argonne MINOS group devoted a substantial effort to the design and prototyping of critical components of the scintillator detector planes. Each of the 584 far detector planes is an 8-m wide octagon composed of 192 plastic scintillator strips. Figure 1 shows a sketch how the strips are arranged in modules on each plane. Each module contains 20 or 28 strips to simplify shipping, handling, installation and testing. The array of strips is glued between thin aluminum skins and the WLS fibers are routed through manifolds to optical connectors. Each module contains a light injection manifold and a short radioactive source tube at each end for trouble shooting and calibration. Scintillator modules for the MINOS near and far detectors will be assembled from commercially supplied components at several “factories” operated by the collaboration.

The Argonne MINOS group is responsible for the development of procedures for the production of extruded scintillator strips, as well as developing most of the assembly machines, quality control equipment and procedures which will be used at the scintillator module assembly facilities. A major accomplishment during the second half of 1998 was the design of a semi-automatic machine for gluing the WLS fibers into the scintillator strip grooves and applying a thin strip of reflective material over the length of the fiber. This was greatly aided by using the mapper, which was already developed at Argonne. The mapper is shown in Figures 2 and 3. It was outfitted as a prototype for the glue machine. Using many of the structures in the mapper, such as the support rails and the drive motor, a glue machine was designed for the large amount of fiber processing which will be needed in the MINOS factories.

Another device which was developed at the Argonne prototype factory for MINOS was a fly cutter for making optical connections with high transmission. The goal was to make very flat plastic surfaces that include embedded optical fibers. This is useful for both the end connector and the cookies that go into the phototube. The fly cutter that was designed at Argonne was both very cost-effective and safe to use on a regular basis. Transmission measurements taken at the University of Indiana confirm that connectors made with this simple device give results that are well within specifications.

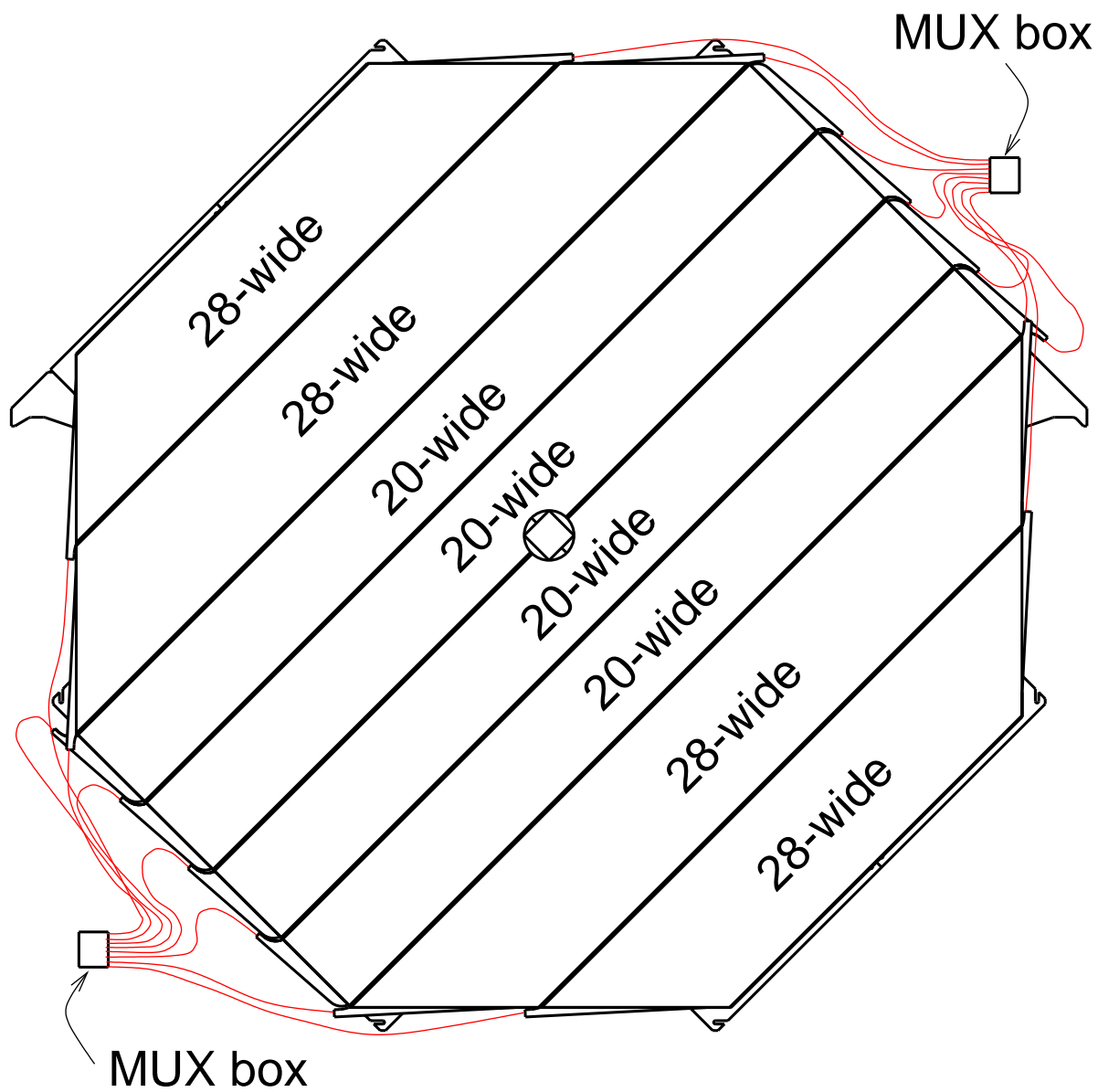


Figure 1. Clear fiber routing and scintillator module layout for readout of one view of scintillator modules for the far detector. Each octagon has eight modules with bulk optical connectors at each end.

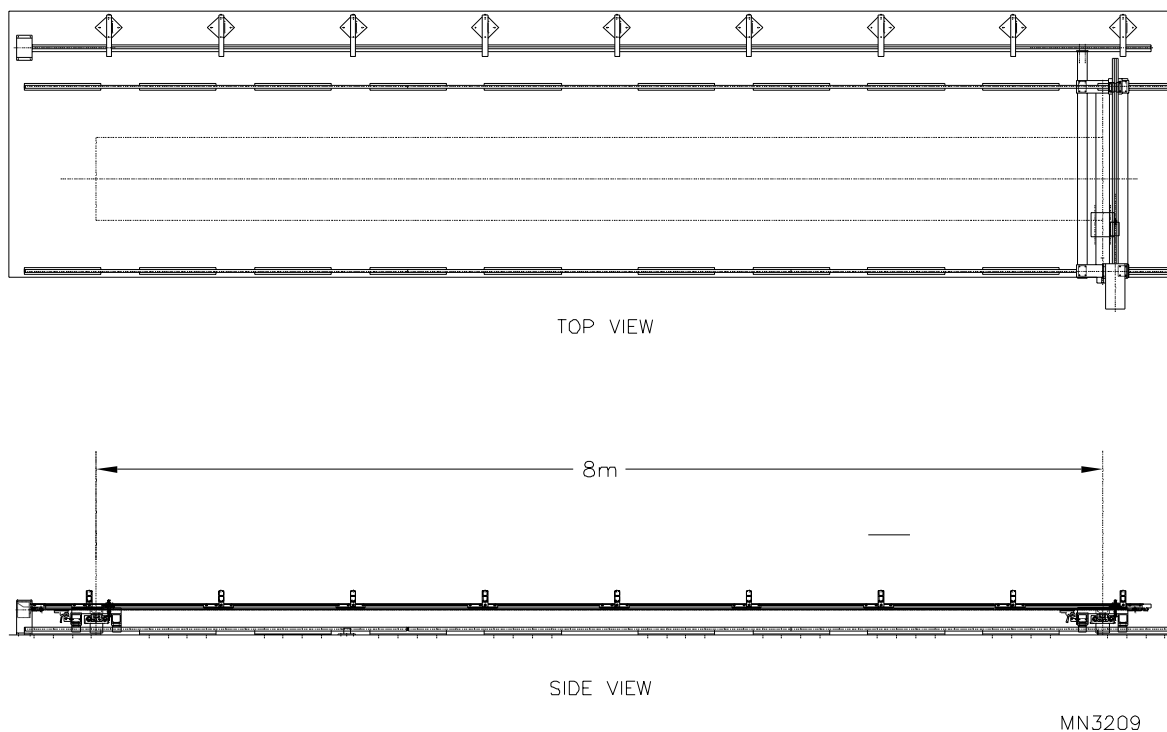


Figure 2. The module mapper. The top and side views of an 8 m long scintillator module are shown.

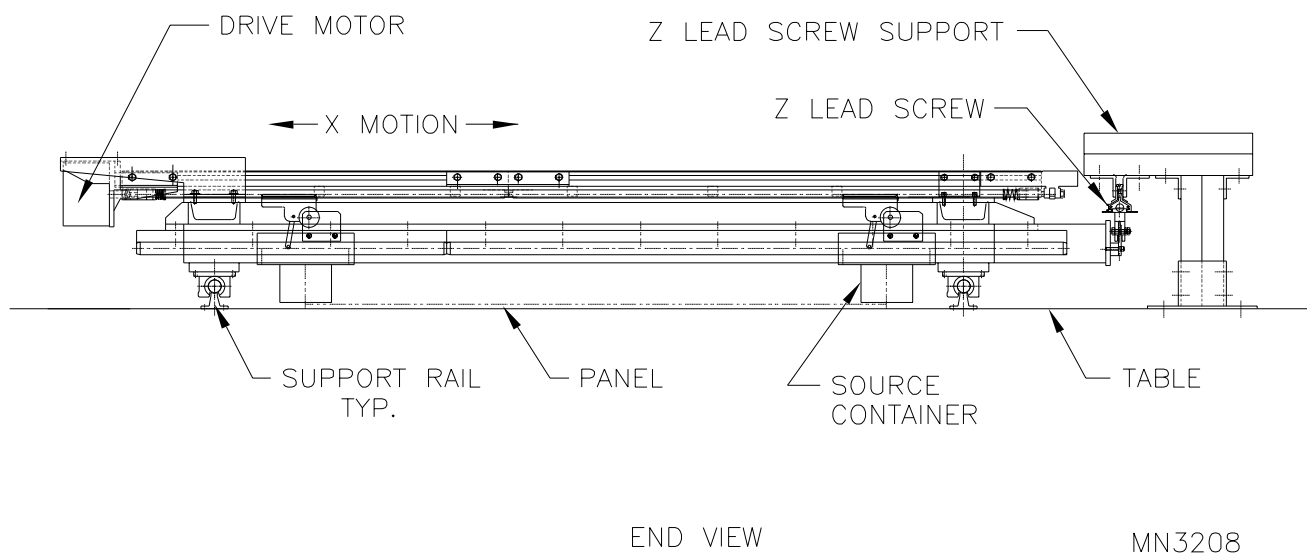


Figure 3. End view of mapper shows details of scanning device and the source container at two extreme position.

(M. C. Goodman)

I.C.5 Electronics Support Group

CDF: We continue with our work in the development of front end electronics for the Shower Max Detector of the CDF Upgrade at Fermilab. For this project, we have overall responsibility for the electronics engineering of the system. The major responsibility in this project involves the coordination of the design engineering and system integration for the entire system, including the development of a custom integrated circuit for the front end electronics, all of the front end boards and crates, and the read-out board which interface to the upper levels of the data acquisition system. This development is a collaboration between Argonne and Fermilab.

In this last period, we oversaw the development of prototypes of all pieces in the system. We are working towards assembling the instrumentation to do a small system test at Fermilab in the early part of 1999.

Besides oversight, we are directly responsible for the specification and testing of the custom integrated circuit for the front end electronics, called the SMQIE. In September, we received the final prototype chips from the foundry. The bare die were wirebonded onto test boards for evaluation. We completed the testing of the chip in November, and the chip performed well. We gave approval for the fabrication of 20,000 chips, which will commence in the early part of 1999. Delivery of packaged parts is expected in June, 1999.

Argonne is also responsible for the design, testing, and production of the daughter boards which contain the SMQIEs, called SQUIDs. Each SQUID contains two SMQIEs, and also other support circuitry for calibration. The first version of the board was completed in the summer of 1998, and was used to evaluate the final SMQIE prototypes. We have purchased 150 of the prototype bare die from the foundry, and will have them wirebonded onto SQUIDs. This will allow us to proceed with small system tests in lieu of having packaged parts. This mini-production effort will begin in the early part of 1999.

Another project that Argonne has direct design responsibility for is the design and production of a VME-based readout board, called the SMXR. This is a sophisticated data processor, which receives digitized data in floating-point form from the front end electronics at the rate of 300 MByte/Sec, adds together up to four words as sampled in time to reconstruct long signals from the detector spread out in time, and also forms trigger bits from the reconstructed signal. The data is stored in a buffer pending read-out by the data acquisition system. The first prototype was developed in the early part of 1998. We are presently working on a second design pass to add functionality, which will be fabricated in the early part of 1999. We anticipate beginning the production of 100 boards in the second half of 1999, pending the successful outcome of small system tests at Fermilab.

In addition to the Shower Max electronics, we are also involved with two other projects for the CDF Upgrade. One project, called the Isolation Trigger, or ISOPICK, receives information from what is called the Cluster Finder, which identifies a group of hit channels in a detector region that might contain an “interesting” event. The isolation trigger performs algorithms on channels around this “cluster” to look for events arising from isolated photons. The ISOPICK sends the result of the algorithms to the second level trigger, as part of the Level 2 Trigger decision. In the first part of 1998, we completed a design pass of the first ISOPICK prototype, and bench testing was done in the fall. We expect to deliver the boards to Fermilab in the early part of 1999 for system tests.

The second project is an interface between the Shower Max system and the second level trigger, and is called RECES. This board also receives cluster information, and looks for events which have a signal pointing from the Tracking Detector into the Central Shower Max Detector. This is used to differentiate events containing electrons from other background events, such as hadronic showers or events with pions, and will help reduce triggers from background events. Design of the first prototype was completed in the fall, and testing is in progress.

ATLAS: We have major responsibilities in the development of electronics for the Level 2 Trigger of the ATLAS Detector at CERN. Working with colleagues from Michigan State University, we are responsible for the development of the Level 2 Trigger Supervisor, and the Region of Interest (ROI) Builder. The system assembles data from the first level trigger describing where data from an “interesting event” can be found, requests buffers to pass the data to available Level 2 processors, and communicates to the buffer when to pass the data to the event builder if the event is selected.

In 1997, the Level 2 Trigger Group engaged in a series of studies to decide on the architecture of the system. Argonne provided both hardware and software support for these studies. In November of 1997, one of the architectures was chosen as the final configuration. Following this decision, a program called the Pilot Project was organized to build and study the system on a medium scale, using a larger network. We are providing both hardware and software support for this effort.

In the spring, 1998, we designed the first prototype of the ROI Builder, which is the interface from the first level trigger. The function of the ROI Builder is to receive a list of addresses from the Level 1 Trigger identifying where the event data from the “Region of Interest,” can be found, collect the addresses on an event by event basis to “build” the event, and make the result available to the Trigger Supervisor for distribution to Level 2 processor. The board uses fast, high-density Field programmable Gate Arrays (FPGAs) to implement the functionality.

The first ROI Builder prototype was built in the fall of 1999. The board was tested at Argonne, and we achieved acceptable performance. We are presently building up a small system which incorporates the ROI Builder as part of the Pilot Project, and will transport the system to Saclay in the early part of 1999, to merge with their system and create a larger network. By the summer of 1999, the system will move to CERN for further testing. It is anticipated that the result of this phase of development will lead to a full specification of the architecture of the Level 2 Trigger System, including the Supervisor and the ROI Builder. We expect that ANL and MSU will have joint responsibility in building these pieces of hardware for the final system.

MINOS: In this last period, we continued our involvement with MINOS, the Neutrino Oscillation Experiment at the Soudan mine. In the fall of 1998, the experiment was reviewed by the Lehman Panel, which looked at the baseline design and cost for the project. We assisted in the preparation for this review by checking designs, costs, and schedules for the development of the read-out electronics. In December, we were asked to take over the Level 3 management of the front end electronics from Oxford, which we accepted. The change was motivated by a reorganization of the UK engineering effort.

One of the remaining technology issues in the project is the choice of the photodetector. The baseline design calls for using Hamamatsu 16 channel multi-anode phototubes. A plan for the electronics has been developed around this photodetector by the UK groups, as described in the Technical Design Report. However, a competing proposal is to replace the phototubes with Hybrid Photodiodes (HPDs), which have several desirable properties including better uniformity and higher efficiency. The primary drawbacks with HPDs are uncertainty in their long-term performance, and that they must be read out by a custom integrated circuit which presently does not exist. The collaboration plans to make this decision in early 1999. Clearly, this decision has a great impact on the design of the electronics. We are currently assisting in the preparations for making this decision by reviewing costs and schedules for the two photodetector choices.

ZEUS: The ZEUS experiment at DESY is planning several upgrades to their experiment. One of the projects is the replacement of the tracking detector in the forward region. The new tracker will use straw tubes, rather than the older-style wire chamber technology. We anticipate being involved in building front end electronics for this new detector. The system would use a custom integrated circuit developed at PENN called the ASDBLR. The chip produces discriminated outputs, which are used to measure the time of an event. The project involves building electronics which will interface to the detector, process the discriminated outputs, and transfer them into the existing data acquisition system.

In the fall of 1998, we received a test board containing the ASDBLR chip from PENN. We have evaluated the chip, and are planning to build a prototype board for the ZEUS

application which contains these chips. The design of this board is in progress. We will have the board ready for testing with the prototype detector in a test beam at DESY by February, 1999.

Another project for the upgrade is the replacement of the high voltage control system, used to power the phototubes in the calorimeter. The old boards are failing, and the boards can no longer be supported due to the older technology used. The design of a new control system is in progress. We plan to test the system at DESY in the spring of 1999.

(G. Drake)

II. THEORETICAL PHYSICS PROGRAM

II.A. THEORY

II.A.1 Associated Production of Gauginos and Gluinos at Hadron Colliders in Next-to-Leading Order SUSY-QCD

Edmond L. Berger, Michael Klasen, and Tim Tait completed the first next-to-leading order (NLO) calculation of the production of gaugino-like charginos and neutralinos in association with gluinos at hadron colliders, including the strong corrections from colored particles and sparticles. They predict inclusive cross sections at the Fermilab Tevatron and CERN LHC. The NLO cross sections are more stable against variations in the hard-scattering scale parameter and are greater than the leading-order values. Their paper, Argonne report ANL-HEP-PR-99-03 has been submitted for publication in *Physics Letters*. A longer paper is in preparation.

Supersymmetry predicts the existence of supersymmetric partners for each of the particles of the standard model. The search for these sparticles is a principal motivation of the forthcoming Run II of the Fermilab Tevatron collider and of the CERN Large Hadron Collider (LHC) program. A potentially important, but heretofore largely overlooked, discovery channel is the associated production of a spin-1/2 gaugino ($\tilde{\chi}$) with a spin-1/2 gluino (\tilde{g}) or with a spin-0 squark (\tilde{q}). Color-neutral gauginos couple with electroweak strength, whereas the colored squarks and gluinos couple strongly. Associated production is therefore a semi-weak process in that it involves one somewhat smaller coupling constant than the pair production of colored sparticles. However, in popular models of SUSY breaking, such as the supergravity (SUGRA) model, the mass spectrum favors much lighter masses for the low-lying neutralinos and charginos than for the squarks and gluinos. This mass hierarchy means that the phase space for production of neutralinos and charginos, the corresponding partonic luminosities, and the production cross sections will be greater than those for gluinos and squarks. These advantages are potentially decisive at a collider with limited energy, such as the Tevatron. Furthermore, associated production has a clean experimental signature. For example, the lowest lying neutralino is the (stable) lightest supersymmetric particle (LSP) in SUGRA models, manifest as missing energy in the events, and it is the second lightest in gauge-mediated models. In models with a very light gluino, there could be large rates for gluino plus gaugino production, with simple signatures, whereas gluino pair production suffers from large hadronic jet backgrounds.

Experimental investigations are facilitated by firm theoretical understanding of the expected sizes of the cross sections for production of the superparticles. In the case of hadron-hadron colliders, the large strong coupling strength (α_s) results in potentially large contributions to cross sections from terms beyond leading order (LO) in a perturbative quantum chromodynamics (QCD) evaluation of the cross section. For accurate theoretical estimates, it is

necessary to extend the calculations to next-to-leading order (NLO) or beyond. NLO contributions generally reduce and stabilize dependence on undetermined parameters such as the renormalization and factorization scales. Before the work of Berger, Klasen, and Tait, associated production had been calculated only in LO.

In their *Letter*, Berger, Klasen, and Tait present the first NLO (in SUSY-QCD) calculation of hadroproduction of a gluino in association with a gaugino, including contributions from virtual loops of colored sparticles and particles and three-particle final states involving the emission of light real particles. They extract the ultraviolet, infrared, and collinear divergences by use of dimensional regularization and employ standard $\overline{\text{MS}}$ renormalization and mass factorization procedures. In the course of computing the virtual contributions, they encountered new divergent four-point functions. The contributions from real emission of light particles were treated with a phase space slicing method. They provide predictions for inclusive cross sections at Tevatron and LHC energies.

(E. L. Berger)

II.A.2 Relativistic Corrections to S -Wave Quarkonium Decays

G. Bodwin and A. Petrelli are continuing their work, described in detail in the January 1–June 30, 1998 report (ANL-TR-98-134), on the computation of higher-order relativistic corrections to the rates for decays of S -wave heavy-quarkonium states into light hadrons. As a check on the calculation of the order- v^4 correction for 3S_1 decay to light hadrons, they are developing a general symbolic-manipulation (Mathematica) method, based on four-vector differentiation, that allows one to isolate contributions of any given order in v for any decay process.

(G. Bodwin and A. Petrelli)

II.A.3 Order- $\alpha_s v^2$ Corrections to J/ψ and Upsilon Decays

G. Bodwin and A. Petrelli have carried out some preliminary work toward a complete calculation of the order- $\alpha_s v^2$ corrections to J/ψ and Upsilon decays to lepton pairs. So far, they have computed some of the Nonrelativistic QCD (NRQCD) corrections that are needed to work out the matching between NRQCD and full QCD, and they have also computed some of the corrections in full QCD. This calculation, combined with the recent calculation by Beneke, Signer, and Smirnov of the order- α^4 corrections, may allow a comparison between data and theory at an increased level of precision.

(G. Bodwin and A. Petrelli)

II.A.4 **Sparticle Production and Photon Hadron Scattering in NLO QCD**

The use of prompt photon production in hadron collisions to extract the parton densities in the proton, in particular that of the gluon, is limited by uncertainties from fragmentation contributions and from the necessity to isolate the photon. Both problems are absent if one uses a slightly off-shell photon with large transverse energy that decays into a lepton pair. Theoretically, the real and virtual photon cross-sections are closely related even at next-to-leading order of QCD [Phys. Rev. **D58**, 074012 (1998)].

In electron-positron collisions at very high energies, a substantial fraction of the cross section comes from the scattering of initial state photons, which have been radiated in bremsstrahlung, beamstrahlung, and laser backscattering mechanisms. Of these three photon radiation mechanisms, only bremsstrahlung is present at muon colliders leading to a smaller, but still sizeable photon scattering cross section. Thus, it will be possible to determine the photon structure at muon colliders (In *Batavia, Physics at the First Muon Collider*, pp. 495-504).

Increased luminosity at the electron-proton collider HERA now allows for the study of multijet production in photon-proton scattering. Theoretical predictions for three-jet production agree well with the ZEUS measurement of different kinematic observables. However, the complexity of the process restricts this calculation to leading order in QCD, which leads to sizeable scale uncertainties (Accepted for publication in Eur. Phys. J. C, ANL-HEP-PR-98-91, hep-ph/9808223).

The discovery or exclusion of supersymmetric particles at hadron colliders depends strongly on solid theoretical cross section predictions in NLO of SUSY-QCD and detailed studies of the final state. Monte Carlo generators have the advantage of producing detailed events resembling those observed experimentally while not giving very precise absolute cross sections. A possible remedy is the implementation of optimized scales in the Monte Carlo generators which can be derived from NLO SUSY-QCD calculations (Accepted for publication in Phys. Rev. **D**, ANL-HEP-PR-98-48, hep-ph/9807230).

(M. Klasen)

II.A.5 **Computational Physics (Lattice Gauge Theory)**

The computational physics effort has been devoted to numerical simulations and measurements in lattice field theories, primarily lattice QCD and other field theories which model its behavior. Transcribing a continuum field theory to a finite lattice reduces it to one with a finite number of degrees of freedom that enables direct numerical simulations while

providing the required ultraviolet regulator. For QCD, such lattice methods provide the only reliable way of calculating non-perturbative properties of the theory. This enables one to calculate such basic properties of hadrons as their masses and decay rates.

In addition, it enables one to study the properties of hot and/or dense hadronic/nuclear matter and its transition to a quark-gluon plasma. Such studies are relevant to the physics of the early universe, neutron stars and relativistic heavy ion collisions such as will be observed at RHIC.

During this period we have tested a class of improved action for the staggered latticization of quarks in lattice QCD, suggested by Lepage, to reduce the flavor symmetry violations, a lattice artifact. This action represents a simplification of the class of action we (Lagaë and Sinclair) had introduced for the same purpose. What we find is that it significantly reduces the splittings of local pions, a major deficiency of the standard staggered action, however not quite as well as our action. What remains to be tested for these (and our) actions is how well they reduce the splittings between local and non-local pions.

In addition, we have continued our simulations of the thermodynamics of lattice QCD with an additional, irrelevant, 4-fermion interaction allowing simulations at zero quark mass. These simulations are enabling us to calculate the critical indices at the transition from hadronic matter to a quark-gluon plasma for 2 flavor QCD on lattices with time extent of 6 (in lattice units), and thus to understand the physics of this second-order transition and eventually to produce an equation of state for hadronic matter near this transition. Although the effects of critical slowing down make this a lengthy set of simulations, we believe that we should complete these simulations by the end of FY99.

Finally, we have been extending our studies of domain-wall quarks on high temperature, quenched QCD configurations. Domain-wall fermions define lattice fermions on a 5-dimensional space, yielding 4-dimensional fermions with exact chiral symmetry when the extent of 5th dimension becomes infinite. What we are testing is how well chiral symmetry is approximated on a lattice of finite extent. At the highest temperature we have considered ($6/g^2=6.2$ on a $16^3 \times 8$ lattice), we find good approximations to the Atiyah-Singer index theorem for a lattice of extent 10 in the 5th dimension, and good agreement with the instanton number measured in this way with that measured directly from the gauge field configurations (using the cooling method). For small fermion masses on a configuration of topological charge Q , we find that $\langle \bar{\psi}\psi \rangle$, $\langle \bar{\psi}\gamma_5\psi \rangle$, and the disconnected part of flavor singlet scalar and pseudoscalar meson propagators are well approximated by the lowest Q eigenvalues of the Dirac operator. We are now extending this calculation to lower temperatures.

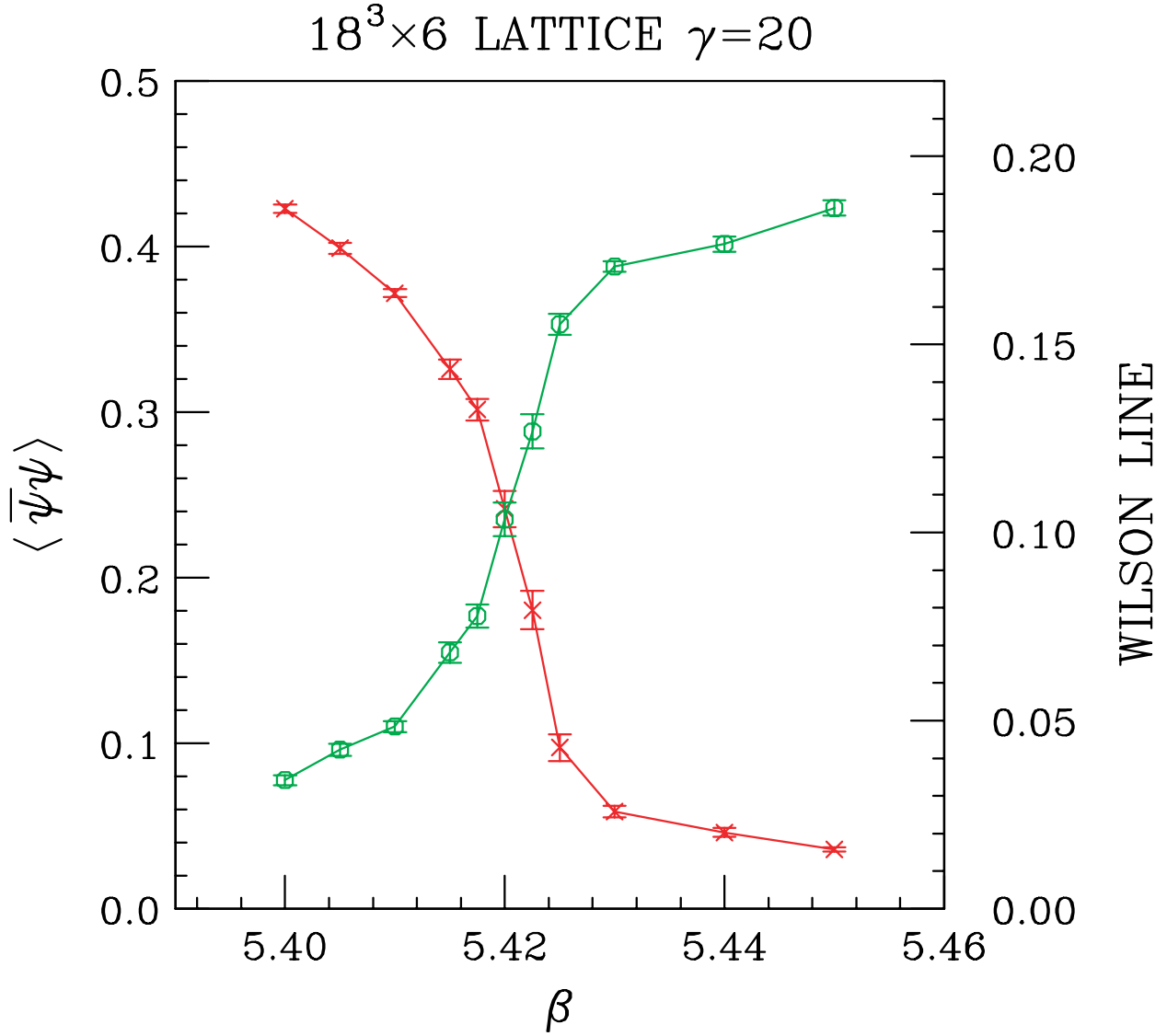


Figure 1. The chiral condensate and Wilson/Polyakov line as functions of $\beta=6/g^2$ on an $18^3 \times 6$ lattice at zero quark mass.

The above simulations were performed on the Cray C90, J90's and T3E at NERSC, and on divisional PC's and workstations.

(D. K. Sinclair and J.-F. Lagaë)

II.A.6 The Triangle Anomaly in Triple-Regge Limits

In a paper that is in preparation, Alan White studies reggeized gluon interactions due to a single quark loop in triple-regge and helicity-pole limits. The purpose is to isolate the massless quark $U(1)$ triangle anomaly as an infrared divergence in reggeon interaction vertices. Regge limits have the virtue that, since high-energy is involved, they are *a-priori* close to perturbation theory at large transverse momentum. Conversely, in the infrared transverse momentum region, which is very tightly controlled by t -channel unitarity, the need for a non-perturbative modification of the theory should become apparent as well as, perhaps, the form this modification should take. Although QCD, of course, contains only vector interactions, in multi-regge limits effective vertices are generated by quark loops which involve products of γ -matrices. The triple-regge limit is sufficiently intricate that both the axial-vector couplings and the orthogonal momenta, needed to generate the triangle anomaly, are present. This is a new infrared manifestation of the $U(1)$ anomaly.

At lowest-order, the anomaly is present only in the contributions of maximally non-planar diagrams. To systematically discuss cancellations, it is necessary to develop a multi-regge asymptotic dispersion relation formalism based on the computation of triple discontinuities. There are 48 triple discontinuities in the dispersion relation which fall into two distinct groups. For one group, which contains the discontinuities related to one-particle inclusive cross-sections, the multi-regge theory is straightforward. The second group contains the anomaly and the multi-regge theory has some special features, including a special signature rule. It appears that when the scattering states are elementary quarks or gluons, the exchanged reggeon states are such that the anomaly cancels. For more general states it need not cancel.

The ultimate goal, outlined in Phys. Rev. **D58**, 074008 (1998), is to show that this dynamical appearance of the anomaly has a deep significance in that, when combined with the infrared divergence structure of gluon and quark reggeon diagrams, it can be responsible for the non-perturbative spectrum of the theory.

(A. R. White)

III. ACCELERATOR RESEARCH AND DEVELOPMENT

III.A. ARGONNE WAKEFIELD ACCELERATOR PROGRAM

III.A.1 Photoinjector Research

Tests have been completed on the photoinjector cavity constructed jointly with the SRRC group (Taiwan). This cavity is similar in design to the existing AWA high current gun but was produced with greater attention to surface finish and was thus expected to be able to attain higher surface fields with significantly smaller dark current levels.

The gun and its attendant RF hardware, solenoids and vacuum equipment were installed on the AWA gun test stand (formerly the TTF gun test stand). Rf conditioning of the gun proceeded smoothly and rapidly. For a peak power of 2 MW and a cathode surface field of 100 MV/m (somewhat larger than the design value of 92 MV/m), the dark current observed was 13 nC/rf pulse, compared to 50 nC/pulse for the present AWA gun at 60 MV/m cathode field.

After further conditioning, the input power was raised to 3 MW, corresponding to a photocathode field of 117 MV/m (nose cone field = 152 MV/m with a measured dark current of 25 nC/pulse. This is 40% above the design field and should provide significantly improved performance over the existing gun.

Work is also proceeding on the design of a new 1-1/2 cell gun which will replace the present AWA source and one linac tank and will permit operation at 100 nC/pulse with a beam energy of 18 MeV and rms bunch length of 1 mm. Design calculations show that normalized transverse emittances < 100 mm mrad can be obtained.

III.A.2 Plasma Wakefield Experiment

The joint plasma Wakefield program with UCLA was completed. The AWA drive beam was passed through a plasma column produced by a hollow cathode arc source provided by UCLA. The beam density was sufficiently large that the plasma was driven into the so-called blowout regime, where all electrons are ejected from the plasma along the beam path, resulting in high fields. Gradients as large as 22 MV/m were observed.

(P. V. Schoessow)

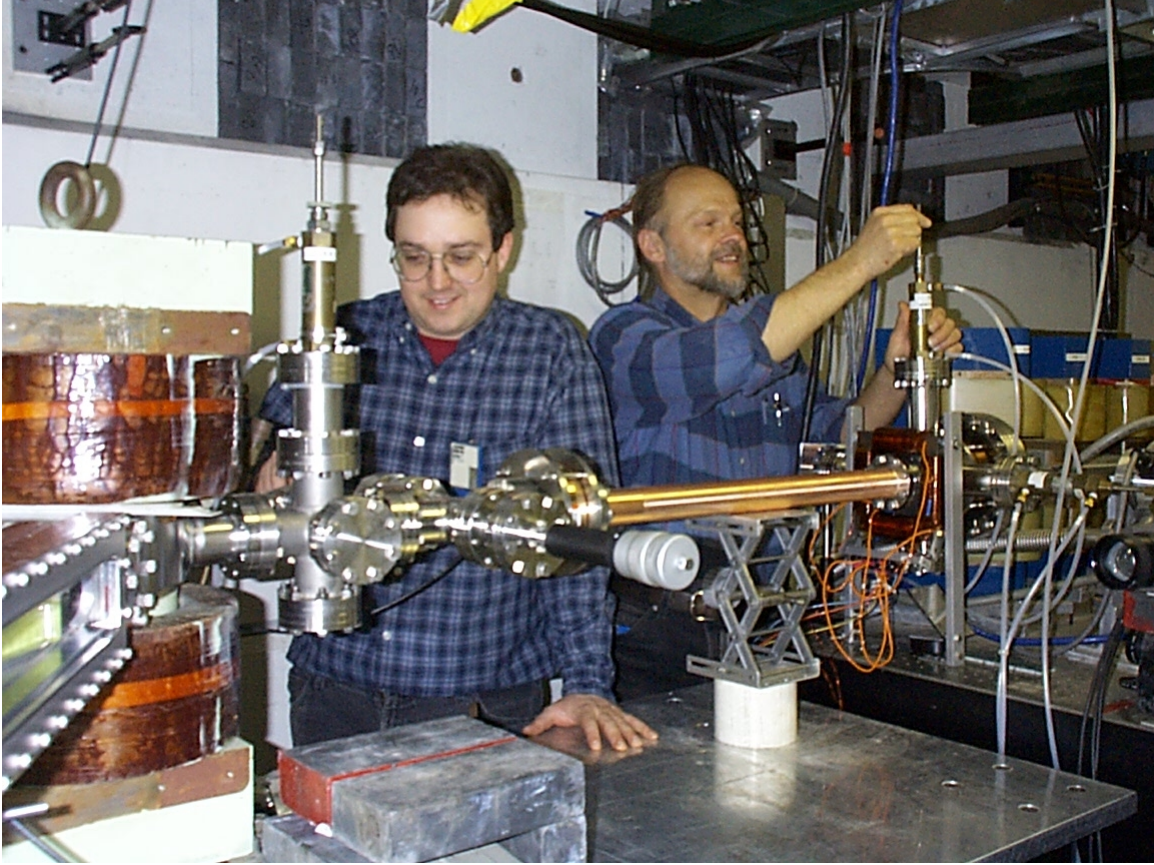


Figure 1. J. Power and R. Konecny installing the Multimode Dielectric Wakefield Accelerator and new high resolution spectrometer.

III.B MUON COLLIDER R & D

III.B.1 Beam Optics in Bent Solenoids

During the reporting period we refined calculations of the bend solenoid used for longitudinal muon cooling, and looked at aberrations that could raise the emittance of the muon beam. When a particle enters a bent solenoid it begins to drift perpendicular to the plane of the bend. This drift can be compensated by introducing a \mathbf{B} field perpendicular to the bend which cancels out the drift. The desired perpendicular field is dependent on the radius of the bend and should be perpendicular to the plane of the bend. Unfortunately, these requirements violate Ampere's Law. The average field around the beam must be nonzero according to beam optics, and must be zero according to Ampere's Law, for a region that does not contain current. Thus the introduction of real perpendicular compensating fields into the optics produces aberrations.

The exact nature of the aberration depends on the coil configuration used to introduce the perpendicular field. There are two options: 1) a homogeneous field produced by large external coils and 2) the field produced by tipping the coils slightly, which produces roughly the correct $1/R$ dependence. Both options introduce shears in the beam, option 1) mostly vertical and 2) mostly horizontal, which effectively rotate the beam around its axis. as shown in Figure 1.

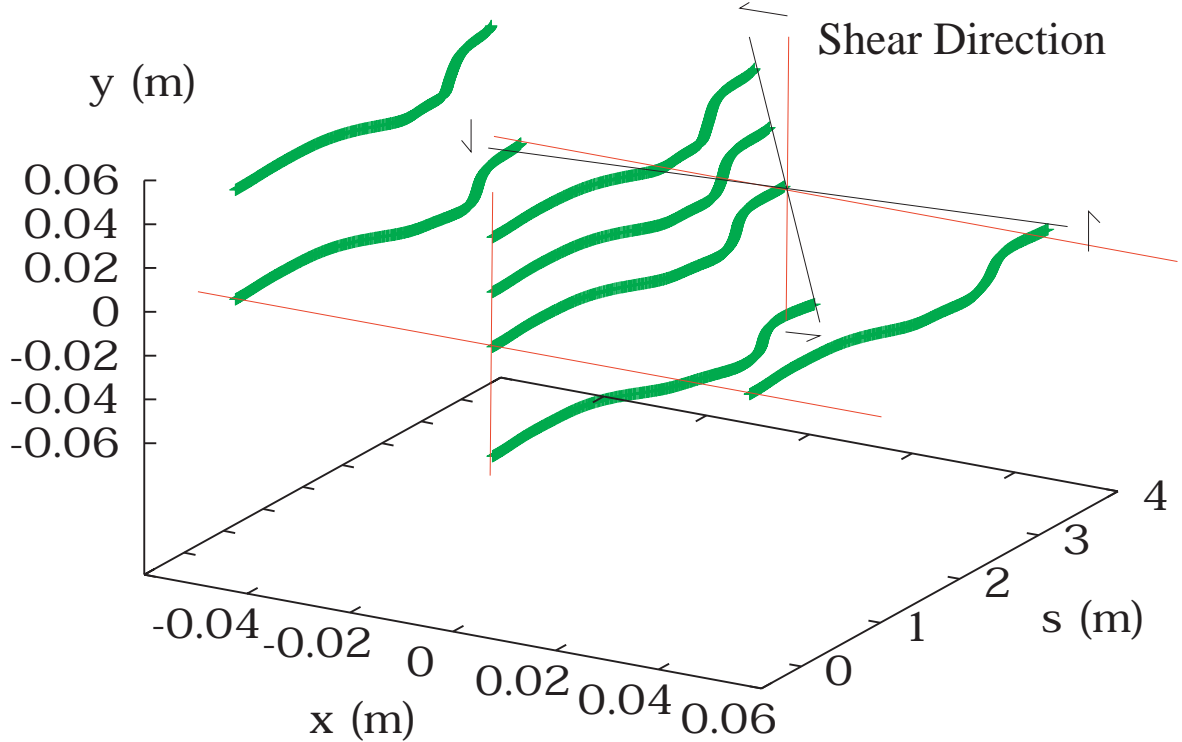


Figure 1. Beam shearing (rotating) in bent solenoids.

A preliminary analysis of the optics of bent solenoids, which stresses the details of the emittance growth, coupling sections and aberrations was completed. The details of this analysis were submitted to Physical Review (and subsequently accepted).

III.B.2 The Design of a Lithium Lens

In addition to work on bent solenoids, considerable effort was devoted to beginning an analysis of the problems of liquid Lithium lenses. These lenses are the last stage of the cooling system, and ultimately determine the event rate in the collider. Unfortunately, producing the smallest emittances would require the largest mechanical stresses on the lenses. The Argonne approach has been to try to produce a self consistent picture of how the last lens would operate and use that to determine how the other lenses could be coupled to it. This problem is partly mechanical engineering and partly beam optics.

The mechanical design of the Lithium lens has been done in a loose collaboration with G. Silvestrov, of Budker Institute of Nuclear Physics, Novosibersk. The BINP approach to the mechanical shock produced by the ohmic and beam heating is radial confinement and longitudinal expansion. Argonne has proposed the option of using compressible insulators which absorb the majority of the shock radially. Initial calculations, using the HEIGHTS package, developed by A. Hassanein, will use a hydrodynamic model to evaluate the heating and mechanical effects from both the electrical current pulse and the beam heating pulse. These calculations will be used as the basis for more detailed mechanical design effort.

The beam optics required to carry the muon beam from one lens to another is difficult because the beam spots at the lenses at either end are small, the length of the line has to be sufficiently long for linacs to reaccelerate the beam, and the momentum spread of the beam is large. An innovation by J. Norem, where the linacs rotate the synchrotron phase of the beam by roughly $\Psi = \pi$ and the transverse optics are longitudinally symmetric around the center of the linac, seems to be the primary option. This method insures the average momentum of the beam down the line to be equal to the design momentum, with chromatic effects from fluctuations above and below the design momentum canceling, to first order. This method has been extended by V. Balbekov at FNAL and tested, using tracking by P. Spentzouris, also of Fermilab.

(J. Norem)

IV. DIVISIONAL COMPUTING ACTIVITIES

IV.A. GRAND CHALLENGE APPLICATIONS:

IV.A.1 Data Access for High-Energy and Nuclear Physics R&D

Two physicists (L. Price and E. May) and a computer scientist (D. Malon) from ANL-DIS division continued to work on the "Grand Challenge Application on HENP Data" project. This is a DOE/ER MICS, HENP-HEP, HENP-NP supported R&D project to provide develop tools to allow High Energy and Nuclear Physicists to analyze and manage the massive amounts of data which will be generated by next generation of experiments. In addition to its direct impact on the success of High Energy and Nuclear Physics experiments this work will also have impact on other governmental and commercial enterprises faced with massive amounts of data. Laboratory and University collaborating partners are LBNL, ANL, BNL, FSU, UCLA, U Tenn., and Yale. For the work in the Atlas-US computing we have been joined in part by two additional physicists (T. LeCompte and R. Wagner).

During this interval we worked in the following areas:

- We attended one collaboration meeting at LBNL. We participated in the "RHIC Mock Data Challenge I" at BNL during September and October using the GCA/HENP data access and storage system to store and analyze STAR and Phenix simulation data. This test was very successful and planning was begun to participate in the RHIC Mock Data Challenge II during early 1999 which will be a full scale dress rehearsal for the first data collection at RHIC during the summer of 1999.
- Considerable effort was made on planning the US-Atlas computing organization. A white paper describing the need, organization and a plan for the US-Atlas computing group was written and presented to a DOE-HEP review panel in Washington, DC during November 1998. Several visits to CERN were made to give presentations and work with the RD45 and Atlas Database groups. The Objectivity based Tilecal testbeam database system was imported and made to function on the PDSF at LBNL. Testing of network access between databases at ANL, LBNL and CERN was conducted. We participated in the SLAC Scientific Data Management Workshop, October 20-22, 1998, which brought together HEP and other DOE Science disciplines to look at common Data Management work and its relationship to the upcoming Strategic Simulation Initiative.

- A paper was presented at the "Computing in High Energy Physics 1998 (CHEP98)" conference titled, "*An Architecture for Optimizing Query Processing and Data Delivery in Multilevel Storage Environments.*"

- We organized and ran the "Computing in High Energy Physics 1998 (CHEP98)" conference which was held in Chicago, August 31 - September 4, 1998, and which was attended by over 400 physicists and computing specialist in High Energy Physics.

(E. N. May)

V. PUBLICATIONS

V.A. JOURNAL PUBLICATIONS, CONFERENCE PROCEEDINGS, BOOKS

A Proton Driver for the Muon Collider Source with a Tunable Momentum Compaction Lattice

J. Norem, *et al.*

Proceedings of the 1997 Particle Accelerator Conference, Vol. 1, edited by M. Comyn, M.K. Craddock, M. Reiser, and J. Thomson (TRIUMF, Vancouver, B.C., Canada, 1998) p. 1030.

An e^+e^- Top Factory in a 50+50 TeV Hadron Collider Tunnel

J. Norem, J. Jagger, and S. Sharma (ANL), *et al.*

Proceedings of the 1997 Particle Accelerator Conference, Vol. 1, edited by M. Comyn, M.K. Craddock, M. Reiser, and J. Thomson (TRIUMF, Vancouver, B.C., Canada, 1998) p. 363.

Bunch Shortening Experiments in the Fermilab Booster and the AGS

J. Norem, *et al.*

Proceedings of the 1997 Particle Accelerator Conference, Vol. 1, edited by M. Comyn, M.K. Craddock, M. Reiser, and J. Thomson (TRIUMF, Vancouver, B.C., Canada, 1998) p. 396.

Charged Particles and Neutral Kaons in Photoproduced Jets at HERA

ZEUS Collaboration, J. Breitweg, *et al.*

Eur. Phys. J. **C2**, 77 (1998)

Confinement and the Supercritical Pomeron in QCD

A. R. White

Phys. Rev. **D58**, 074008 (1998)

Direct Reconstruction of np Elastic Scattering Amplitudes Between 0.80 and 1.1 GeV

H. Spinka and D. Lopiano (ANL), *et al.*

IL NUOVO CIMENTO 111A, (1) 13 (1998)

Elastic and Proton-Dissociative ρ^0 Photoproduction at HERA

ZEUS Collaboration, J. Breitweg, *et al.*

Eur. Phys. J. **C2**, 247 (1998)

Event Shape Analysis of Deep Inelastic Scattering Events with a Large Rapidity Gap at HERA

ZEUS Collaboration, J. Breitweg, *et al.*

Phys. Lett. **B421**, 368 (1998)

Events with a Rapidity Gap between Jets in $\bar{p}p$ Collisions at $\sqrt{s} = 630$ GeV

The CDF Collaboration, F. Abe, *et al.*

Phys. Rev. Lett. **81**, 5278 (1998)

Externally Powered Dielectric Loaded Waveguides as Accelerating Structures

W. Gai, R. Konecny, and J. Simpson

Proceedings of the 1997 Particle Accelerator Conference, Vol. 1, edited by
M. Comyn, M.K. Craddock,
M. Reiser, and J. Thomson (TRIUMF, Vancouver, B.C., Canada, 1998)
p. 636.

Features of Time-Independent Wigner Functions

T. Curtright, D. Fairlie, and C. Zachos

Phys. Rev. **D58**, 025002 (1998)

Generation and Acceleration of High Charge Short Electron Bunches

M. E. Conde, W. Gai, R. Konecny, X. Li, J. Power, P. Schoessow, and N. Barov
Phys. Rev. Special Topics - Accelerators and Beams, Vol. 1, 041302,
(1998)

High Gradient Dielectric Wakefield Device Measurements at the Argonne Wakefield Accelerator

P. Schoessow, M. Conde, W. Gai, R. Konecny, J. Power, and J. Simpson

Proceedings of the 1997 Particle Accelerator Conference, Vol. 1, edited by
M. Comyn, M.K. Craddock,
M. Reiser, and J. Thomson (TRIUMF, Vancouver, B.C., Canada, 1998)
p. 639.

Massive Lepton Pairs as a Prompt Photon Surrogate

E. L. Berger, L. E. Gordon, and M. Klasen

Phys. Rev. **D58**, 074012 (1998)

Measurement of Elastic Υ Photoproduction at HERA

ZEUS Collaboration, J. Breitweg, *et al.*

Phys. Lett. **B437**, 432 (1998)

Measurement of the $B_d^0 - \bar{B}_d^0$ Flavor Oscillation Frequency and Study of Same Side Flavor Tagging of B Mesons in $p\bar{p}$ Collisions

The CDF Collaboration, F. Abe, *et al.*

Phys. Rev. **D59**, 032001 (1998)

Measurement of the B^- and \bar{B}^0 Meson Lifetimes Using Semileptonic Decays

The CDF Collaboration, F. Abe, *et al.*

Phys. Rev. **D58**, 092002 (1998)

Measurement of the $\sigma(W^+ \geq 1\text{Jet}) / \sigma(W)$ Cross Section Ratio from $p\bar{p}$ Collisions at $\sqrt{s} = 1.8 \text{ TeV}$

The CDF Collaboration, F. Abe, *et al.*
Phys. Rev. Lett. **81**, 1367 (1998)

Measurement of the t Distribution in Diffractive Photoproduction at HERA

ZEUS Collaboration, J. Breitweg, *et al.*
Eur. Phys. J. **C2**, 237 (1998)

Measurement of the Lepton Charge Asymmetry in W-boson Decays Produced in $p\bar{p}$ Collisions

The CDF Collaboration, F. Abe, *et al.*
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L. E. Gordon, M. Goshtasbpour, and G. P. Ramsey
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V.B. PAPERS SUBMITTED FOR PUBLICATION

A Useful Approximate Isospin Equality for Charmless Strange B Decays

H. J. Lipkin

Phys. Lett.

ANL-HEP-PR-98-123

Coupling Sections, Emittance Growth, and Drift Compensation in the use of Bent Solenoids as Beam Transport Elements

J. Norem

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ANL-HEP-PR-98-139

Degeneration of ALF D_n Metrics

G. Chalmers, M. Roček, and S. Wiles

JHEP

ANL-HEP-PR-98-140

Higgs-Boson Production in Association with Bottom Quarks at Next-to-Leading Order

D. Dicus, T. Stelzer, Z. Sullivan, and S. Willenbrock

Phys. Rev. D

ANL-HEP-PR-98-138

Kinematics of $t\bar{t}$ Events at CDF

The CDF Collaboration, F. Abe, *et al.*

Accepted for publication in Phys. Rev. D.

MSSM Higgs Boson Phenomenology at the Tevatron Collider

M. Carena, S. Mrenna, and C.E.M. Wagner

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ANL-HEP-PR-98-54

Measurement of Inclusive $D^* \pm$ and Associated Dijet Cross Sections in Photoproduction at HERA

ZEUS Collaboration, J. Breitweg, *et al.*

Submitted to Eur. Phys. J.

ANL-HEP-PR-99-68

Measurement of Z^0 and Drell-Yan Production Cross Section Using Dimuons in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

The CDF Collaboration, F. Abe, *et al.*

Submitted to Phys. Rev. D

ANL-HEP-PR-99-10

Measurement of the B_s^0 Meson Lifetime Using Semileptonic Decays

The CDF Collaboration, F. Abe, *et al.*

Submitted to Phys. Rev. D

ANL-HEP-PR-99-11

Measurement of the Top Quark Mass with the Collider Detector at Fermilab

The CDF Collaboration, F. Abe, *et al.*

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Probing Higgs Bosons with Large Bottom Yukawa Coupling at Hadron Colliders

C. Balázs, J. L. Diaz-Cruz, H.-J. He, T. Tait, and C.-P. Yuan

Phys. Rev. D

ANL-HEP-PR-98-55

Renormalon Ambiguities in NRQCD Operator Matrix Elements

G. T. Bodwin and Y.-Q. Chen

Phys. Rev. D

ANL-HEP-PR-98-29

Single Top Production as a Window to Physics Beyond the Standard Model

T. Tait and C.-P. Yuan

Phys. Lett. B

ANL-HEP-PR-98-124

Spin Structure of the Proton and Large p_T Processes in Polarized pp Collisions

L. E. Gordon and G. P. Ramsey

Phys. Rev. D

ANL-HEP-PR-98-92

The Atmospheric Neutrino Flavor Ratio from a 3.9 Fiducial Kiloton-Year Exposure of Soudan 2

D. S. Ayres, T. H. Fields, M. C. Goodman, T. Joffe-Minor, W. Leeson,

L. E. Price, R. Seidlein, J. L. Thron, and the Soudan 2 Collaboration

(W.W.M. Allison, *et al.*)

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ANL-HEP-PR-99-02

The Large- N Limit of Four-Point Functions in $N=4$ Super Yang-Mills Theory via Anti-de Sitter Supergravity

G. Chalmers and K. Schalm

Nucl. Phys. B

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Three Jet Cross Sections in Photoproduction at HERA

M. Klasen

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Wigner Trajectory Characteristics in Phase Space and Field Theory

T. Curtright and C. Zachos

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V.C. PAPERS OR ABSTRACTS CONTRIBUTED TO CONFERENCES

Domain Wall Fermions at Finite Temperature

J.-F. Lagaë and D. K. Sinclair

XVI International Symposium on Lattice Field Theory (LATTICE '98),
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ANL-HEP-CP-98-66

Four-Point Correlation Functions in the AdS/CFT Correspondence

G. Chalmers and K. Schalm

Trends in Mathematical Physics Conference, Knoxville, TN, October 14-16,
1998.

ANL-HEP-CP-98-142

Local Topological and Chiral Properties of QCD

Ph. de Forcrand, M. Garcia Perez, J. E. Hetrick, E. Laermann, J.-F. Lagaë, and
I.-O. Stamatescu

XVI International Symposium on Lattice Field Theory (LATTICE '98),
Boulder, CO, July 13-18, 1998.

ANL-HEP-CP-98-65

Quantum Mechanics of Neutrino Oscillations—Hand Waving for Pedestrians

H. J. Lipkin

Europhysics, Neutrino Oscillation Workshop (NOW'98), Amsterdam, The
Netherlands, September 7-9, 1998.

ANL-HEP-CP-98-126

Search for New Physics in $D^\pm \rightarrow K_S X^\pm$ and $D^\pm \rightarrow K_S K_S K^\pm$

H. J. Lipkin

Workshop on Heavy Quarks at Fixed Target (HQ'98), Batavia, IL, October
10-12, 1998.

ANL-HEP-CP-98-122

Solving QCD Via Multi-Regge Theory

A. R. White

Theory Institute on Deep Inelastic Diffraction, Argonne, IL, September 14-16, 1998.

ANL-HEP-CP-98-121

SUSY Production Cross Sections

E. L. Berger, B. Harris, M. Klasen, and T. Tait

Proceedings of the *Workshop on Physics at Run II – Supersymmetry/Higgs*, FNAL, Batavia, IL, November 14-16, 1998.

ANL-HEP-CP-98-93

Thermodynamics of Lattice QCD with Massless Quarks and Chiral 4-Fermion Interactions

J. B. Kogut, J.-F. Lagaë, and D. K. Sinclair

XVI International Symposium on Lattice Field Theory (LATTICE '98), Boulder, CO, July 13-18, 1998.

ANL-HEP-CP-98-101

V.D. TECHNICAL REPORTS AND NOTES

B-98-011

The Number of Beam Kaons in July 1998 Data

C. Allgower, R. Manweiler, H. Spinka (ANL) A. Gibson, *et al.*

CDF

ANAL/JET/CDFR/4822

12/03/98

A Measurement of the Photon + Muon Cross Section for Run 1b

K. Kurino, S. Kuhlmann

ANAL/JET/CDFR/4798

10/30/98

Z to ee Peak using Central Crack Chambers

S. Kuhlmann

DOC/CALORIMETRY/CDFR/4694

Proposal to Instrument the Central and Plug EM Phototubes with TDCs

H. Frisch and R. Wagner

DOC/TRIGGER/CDFR/4691

8/95/98

Run 1b Level 2 CEM_8_CFT_7_5 and XCES Electron Trigger Efficiencies

W. J. Taylor, K. Byrum, P. K. Sinervo

ANAL/JET/CDFR/4681

7/28/98

Jet Energy Resolution Using Calorimeter, Tracking and Shower Max Information
A. Bocci, D. Costanzo, S. Kuhlmann, S. Lami, and R. Paoletti

PUB/ELECTROWEAK/PUBLIC/4676

7/21/98

The Measurement of the Mass of the W Boson from the Tevatron
R. Thurman-Keup, The CDF Collaboration

Proceedings of the 2nd Latin America Symposium on High Energy Physics
(SILAFAE 98), San Juan, Puerto Rico, April 8-11, 1998.
FERMILAB-CONF-98/228-E.

PDK

- 711 Isolation of Candidate Nucleon Decay “Mercedes” Events in the
CEV Multiprong Sample
W. Leeson and M. C. Goodman
- 713 Seasonal Effects at Soudan 2
J. Uretsky
- 715 Atmospheric Neutrino Studies in Soudan 2 [1]
Earl Peterson for The Soudan 2 Collaboration (W.W.M. Allison, *et al.*)
- 717 The Atmospheric Neutrino Flavor Ratio from a 3.9 Fiducial Kiloton-Year
Exposure of Soudan 2
D. S. Ayres, T. H. Fields, M. C. Goodman, T. Joffe-Minor, W. Leeson,
L. E. Price, R. Seidlein, J. L. Thron, and The Soudan 2 Collaboration
(W.W.M. Allison, *et al.*)

Submitted to Phys Lett. B (December 1998)
ANL-HEP-PR-99-02

Wakefield:

- WF-181 Resonant Excitation of High Gradient Plasma Wakefield Acceleration by a Train
of Micron Sized Pulses
W. Gai

VI. COLLOQUIA AND CONFERENCE TALKS

Edmond L. Berger

Lepton Pair Production in Hadron Collisions—A Prompt Photon Surrogate
Physics Department, University of Kentucky, Lexington, December 3, 1998.

The Snowmass Experience in Particle Physics
Meeting of the Executive Committee of the Division of Plasma Physics of the
American Physical Society, San Diego, CA, August 6, 1998.

Gordon Chalmers

Correlators in the AdS/CFT Correspondence
LPTHE, Paris VI-VII, France, December 9-18, 1998.

Correlators in the AdS/CFT Correspondence
Niehls Bohr Institut, Copenhagen, Denmark, December 6-8, 1998.

Correlators in the AdS/CFT Correspondence
NIKHEF, Amsterdam, The Netherlands, December 3-4, 1998.

Correlators in the AdS/CFT Correspondence
Utrecht University, The Netherlands, December 1-2, 1998.

Correlators in the AdS/CFT Correspondence
CERN, Geneva, Switzerland, November 2-30, 1998.

Self-Dual Field Theories, Perturbative QCD, and N=2 Strings
CERN, Geneva, Switzerland, November 2-30, 1998.

Self-Dual Field Theories, Perturbative QCD, and N=2 Strings
Institut fuer Theoretische Physik, Hannover, Germany, October 27 - November 1,
1998

String Theory: Old and New
HEP Division Lunch Seminar, ANL-HEP, October 20, 1998.

Correlators in the AdS/CFT Correspondence
Trends in Mathematical Physics Conference, University of Tennessee, Knoxville,
October 14-16, 1998.

N=4 Super Yang-Mills Theory and the AdS/CFT Correspondence
M Theory and Black Holes Workshop, Aspen, CO, September 1-20, 1998.

Maury C. Goodman

Neutrino Oscillations, Dark Matter and Nucleon Decay in Soudan 2

Invited talk for seminar at the Stanford Linear Accelerator Center, Stanford, CA,
November 19, 1998.

Michael Klasen

Low Mass Lepton Pair Production in Hadron Collisions

University of Michigan, Ann Arbor, MI, October 2, 1998.

Low Mass Lepton Pair Production in Hadron Collisions

University of Illinois at Urbana-Champaign, September 14, 1998.

Jean-Francois Lagaë

Local Topological and Chiral Properties of QCD

XVI International Symposium on Lattice Field Theory (LATTICE '98), Boulder, CO,
July 17, 1998.

Domain Wall Fermions at Finite Temperature

XVI International Symposium on Lattice Field Theory (LATTICE '98), Boulder, CO,
July 15, 1998.

Harry J. Lipkin

Quantum Mechanics of Neutrino Oscillations—Hand Waving for Pedestrians

Neutrino Oscillation Workshop (NOW'98), Amsterdam, The Netherlands, September
9, 1998.

Search for New Physics in $D^\pm \rightarrow K_S X^\pm$ and $D^\pm \rightarrow K_S K_S K^\pm$

Workshop on Heavy Quarks at Fixed Target (HQ'98), Batavia, IL, October 10-12,
1998.

David M. Malon

An Architecture for Optimizing Query Processing and Data Delivery in Multilevel
Storage Environments

Computing in High Energy Physics 1998, Chicago, IL, September 1998.

Physics Analysis with the GCA Architecture
STAR Collaboration Meeting, Brookhaven, NY, July 28, 1998.

RHIC Event Stores: Mock Data Challenge I and the US DOE Grand Challenge Project
RD45 Workshop, Geneva, Switzerland, October 27, 1998.

James Norem

The Muon Collider
Department Colloquium, University of Houston Department of Physics,
Houston, TX, September 20, 1998.

Gordon Ramsey

Polarized Parton Distributions for Spin Asymmetries
Symposium on High Energy Spin Physics, IHEP, Protvino, Russia, September 8,
1998.

Donald K. Sinclair

Improved Actions for Staggered Fermions
Workshop on Lattice Quantum Chromodynamics, Adelaide, South Australia,
December 7-18, 1998.

Thermodynamics of Lattice QCD with Massless Quarks and Chiral 4-Fermion
Interactions
XVI International Symposium on Lattice Field Theory (LATTICE '98), Boulder, CO,
July 15, 1998.

Harold M. Spinka

ANL-HEP Medium Energy Physics Program
High Energy Physics Division Seminar, ANL, December 2, 1998.

Zack Sullivan

The Dangerous Beauty of Single-Top-Quark Production
High Energy Physics Division Lunch Seminar, ANL, December 8, 1998.

The Dangerous Beauty of Single-Top-Quark Production
Department of Physics, University of Chicago, December 7, 1998.

Timothy Tait

The Electroweak Symmetry Breaking, and the Third Family

Department of Physics, University of Wisconsin, Madison, December 11, 1998.

Alan R. White

Summary of Discussion Sessions and Questions for the Future

4th Small-x Workshop on Diffractive Physics, Batavia, IL, September 20, 1998.

Solving QCD Via Multi-Regge Theory

Theory Institute on Deep Inelastic Diffraction, Argonne, IL, September 14, 1998.

Solving QCD Via Multi-Regge Theory

IXth International Workshop on Small-x Physics and Light-Front Dynamics in QCD,
St. Petersburg, Russia, July 6-14, 1998.

Cosmas Zachos

Quantum Mechanics Lives and Works in Phase Space

Department of Physics, University of Wisconsin, Madison, December 18, 1998.

Quantum Mechanics Lives and Works in Phase Space

Department of Physics, University of Iowa, Iowa City, October 19, 1998.

VII. HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES

David S. Ayres

Deputy Spokesperson for the MINOS Collaboration.

Edmond L. Berger

Adjunct Professor of Physics, Michigan State University, East Lansing, MI, 1997-present.

Member, CTEQ Collaboration

Member, High Energy and Nuclear Physics Advisory Committee, Brookhaven National Laboratory, 1995-2001.

Chair, Subgroup on SUSY Production Cross Sections, Fermilab Workshop on Physics at Run II -- Supersymmetry/Higgs, Batavia, IL, November 19-21, 1998.

Convenor, Physics at Run II Working Group on Photons and Weak Bosons, Fermilab, Batavia, IL, January - December, 1999.

Member, Scientific Program Committee, Recontres de Moriond, "QCD and High Energy Hadronic Interactions," Les Arcs, France, March 1998 and March 1999.

Organizing Committee, Seventh Conference on the Intersections Between Particle and Nuclear Physics, May-June, 2000.

Member, Local Organizing Committee, International Conference on Kaon Physics (K'99), University of Chicago, Chicago, IL, June 21-26, 1999.

Member, International Advisory Committee, Eighth International Conference on Hadron Spectroscopy, Beijing, China, August, 1999.

International Advisory Committee, Frontiers in Science '99, Blois, France, June-July, 1999.

Geoffrey T. Bodwin

Organizer, Greater Chicagoland Particle Theory Meeting, Argonne, IL, October 5, 1998.

Karen Byrum

FNAL Users Executive Committee.

Wei Gai

Member, Advanced Accelerator Workshop Scientific and Organizing Committee.

Maury C. Goodman

Member, MINOS Executive Committee.

Member, Particle Data Group.

Discussion Group Chairman, The Neutrino Oscillation Workshop, Amsterdam,
The Netherlands, September, 1998.

David M. Malon

Organizer and moderator, "Are we ready for object databases, and are they ready for us,"
Plenary panel, Computing in High Energy Physics 1998, Chicago, IL, September 1998.

Edward N. May

Member, staff of ESnet Steering Committee.

Lawrence J. Nodulman

Convener for the 17th International Workshop on Weak Interactions and Neutrinos
(WIN99), January 1999.

James Norem

Muon Collider Group, Technical Committee.

Lawrence E. Price

Chair, Esnet Steering Committee.

Harold M. Spinka

Chairman, Technical, Cost, and Schedule Review for the Los Alamos $n + p \rightarrow d + \gamma$
experiment.

Co-spokesman, BNL E913 experiment which collected data during 1998.

Alan R. White

Member, Program Committee, XXIXth International Symposium on Multiparticle Dynamics, Brown University, Providence, RI, August, 1999.

Co-Organizer, Fourth Workshop on Small-x and Diffractive Physics, Batavia, IL, September 17-20, 1998.

Organizer, Theory Institute on Diffractive Physics, Argonne, IL, September 14-16, 1998.

Member, International Advisory Committee, Xth International Symposium on Very High Energy Cosmic Ray Interactions, Gran Sasso, Italy, July 12-17, 1998.

Rikutarō Yoshida

Deputy Spokesman for ZEUS.

Cosmas Zachos

Member, Editorial Board, Journal of Physics A: Mathematical and General, (UK).

VIII. HEP DIVISION RESEARCH PERSONNEL

Administration

L. Price

D. Hill

Accelerator Physicists

M. Conde

J. Power

W. Gai

P. Schoessow

J. Norem

Experimental Physicists

D. Ayres

B. Musgrave

R. Blair

L. Nodulman

K. Byrum

J. Proudfoot

S. Chekanov

J. Repond

M. Derrick

H. Spinka

T. Fields

R. Stanek

M. Goodman

R. Talaga

D. Krakauer

J. Thron

S. Kuhlmann

R. Thurman-Keup

T. LeCompte

D. Underwood

T. Joffe-Minor

R. Wagner

W. Leeson

A. Wicklund

S. Magill

A. Yokosawa

E. May

R. Yoshida

Theoretical Physicists

E. Berger

S. Mrenna

G. Bodwin

A. Petrelli

G. Chalmers

D. Sinclair

B. Harris

Z. Sullivan

M. Klasen

A. White

J. -F. Lagaë

C. Zachos

Engineers, Computer Scientists, and Applied Scientists

J. Dawson

N. Hill

G. Drake

J. Schlereth

V. Guarino

X. Yang

W. Haberichter

Technical Support Staff

I. Ambats
A. Caird
G. Cox
D. Jankowski
T. Kasprzyk
C. Keyser
L. Kocenko

R. Konecny
Z. Matijas
E. Petereit
L. Reed
R. Rezmer
R. Taylor
K. Wood

Laboratory Graduate Participants

C. Allgower
J. Breitweg
A. Hardman

D. Mikunas
T. Tait
H. Zhang
P. Zou

Visiting Scientists

J. Bartels (Theory)
E. Kovacs (Theory)
H. Lipkin (Theory)

G. Ramsey (Theory)
J. Uretsky (Theory)
T. Wong (AWA)